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IRRIGATED PASTURE FOR STEERS AND LAMBS

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CONTENTS

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IRRIGATED PASTURE FOR STEERS AND LAMBS[1]

THE FINDINGS

This bulletin describes a series of animal experiments, conducted at Davis, to establish principles and methods for best utilization of irrigated pasture, emphasizing those factors that may be controlled by the pasture operator. The following is a summary of the findings and some recommendations.

Grazing management. Forage yield varies with species, variety and season. A simple, highly productive, palatable mixture of grasses and legumes should be grown. The pasture operator can take advantage of seasonal growth characteristics, soil conditions, recovery after grazing, bloat potential and stocking rate of a mixture. Sheep, because of their superior selective grazing ability, will fatten to an acceptable slaughter grade on good irrigated pasture. This is not true for cattle. Under conditions of strip, daily, or weekly rotational grazing, the most beef per acre is achieved by a weekly movement of cattle to another field where the forage is growing rapidly and the stocking rate is slightly higher than that which gives optimum individual animal performance. Under conditions of one-field continuous-grazing the most beef per acre is realized when cattle are grazed for the optimum individual performance. At the present time, continuous grazing is not recommended over rotational grazing because such factors as water use and soil compaction have not been clarified.

Grazing behavior. The time an animal will spend grazing and ruminating increases as feed available decreases. The TDN content of the diet that sheep select on the fifth day in a field is the same as that selected on the second day. Sheep, being more selective, choose a more nutritious diet than cattle, especially when they are grazing a tall crop such as alfalfa. Increased stocking rate increase grazing time up to a point (10 hours per day) and then remain constant even if available forage decreases below animal needs. Grazing behavior can determine what type of animal and what endproduct is to be selected.

Soilage. The greatest beef production per acre from forage results from soilage followed by haying and then pasturing the same crop. The average increase in meat yield per acre has been 30 percent over other methods of harvesting the same crop. Soilage should not be fed as a fattening diet to sheep because, if forced to eat all the forage plant, they are unable to select a highly nutritious ration. Soilage for cattle produces lower gains than grazing but more beef per acre because of increased food intake from a soilage diet. Soilage can produce 1,000 pounds of beef or more per acre.

Supplementation. An additional source of energy, along with a forage diet, is needed to produce an acceptable slaughter steer in a reasonable time period. Continuous supplementation of alfalfa soilage is more satisfactory than supplementation during only the last half of the feeding period, or none at all. Concentrates should be fed, along with soilage, at the rate of 0.5 pounds per 100 pounds body weight to increase dressing percentage and carcass grades to a satisfactory degree. This amount of concentrate supplementation may or may not increase daily gains. Limited supplementation for animals grazing irrigated pasture does not give a satisfactory increase in carcass quality. Feeding free choice, barley or milo, to steers grazing high-quality irrigated pasture at double the normal stocking rate is a satisfactory method of obtaining an acceptable slaughter animal in a reasonable feeding period.

Energy requirements for grazing. These studies did not show that increased digestible energy or increased maintenance requirements are necessary for grazing animals.

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Compensatory growth. A growth rate greater than normal in animals of the same chronological age can be obtained by cattle on irrigated pasture following a low-energy wintering ration. This increased growth rate also occurs in the feedlot following pasturing if stocking rate on pasture is severe enough to limit rate of gain. The length of time and the amount of energy needed above maintenance will determine when to take advantage of compensatory growth. Compensatory growth occurs because of increased feed capacity and increased efficiency of energy utilization.

The role of irrigated pasture. Irrigated pasture is a good growing ration but will not produce "fat" cattle. As a sole source of energy it is expensive in relation to feedlot fattening, but has the advantage of enabling the pasture operator to influence compensatory growth. As a protein source it is very economical especially when used as a protein, vitamin, and mineral source when free choice feeding grain. The varying growth rates that can be obtained when using irrigated pastures can have a definite effect on the economics of producing and fattening beef cattle.

Irrigated pastures have become an important factor in land utilization in California. They provide not only a significant role in the economy of many areas but also provide an important part of the forage for California's meat industry. These pastures have helped to diversify and balance feed production as well as to conserve and improve the soil on many farms.

Sound management is required to meet the challenging problems of irrigated pastures. Management must utilize all that is known and must put into effect quickly new research developments. Considerable progress has been made from available information about the necessity for proper land grading allowing adequate slope, irrigation requirements in both amount and frequency of application, advantages and limitations of individual species, formulation of suitable mixtures, weed control, and application of commercial fertilizers (Peterson *et al.,* 1959; Martin *et al.,* 1965).

GENERAL MANAGEMENT AND PROCEDURES

The studies reported were conducted at the University of California at Davis (figure 1). The grazing trials were conducted during the months of May through September over a period of eleven years (1954–1965).

A uniform field planted initially to birdsfoot trefoil and orchardgrass (*Lotus corniculatus,* narrow leaf and *Dactylis glomerata var. Akaroa*) was used for these studies. Two years later ladino clover (*Trifolium repens var. latum*) was seeded into the existing pasture sod to increase the proportion of legumes because the number of trefoil plants had been drastically reduced. At the end of the 1962 grazing season, the pastures were again overseeded with orchardgrass and ladino clover and strawberry clover and ryegrass (*Trifolium fragiferum var. Salina* and *Lolium perene*).

The forages were produced on irrigated fields. Rain was not a factor in maintaining a strict pasture rotation, producing high-quality hay or inhibiting the soilage operations [average annual rainfall, May through September 1.0 in.; average maximum temperature 90°F and average minimum temperature 51°F.]. Pasture irrigation was conducted so as to avoid plant moisture stress. The irrigation water was applied by flooding, using the border method. In general, 30 units of nitrogen were applied per month to the fields after the first flush of spring growth was re-

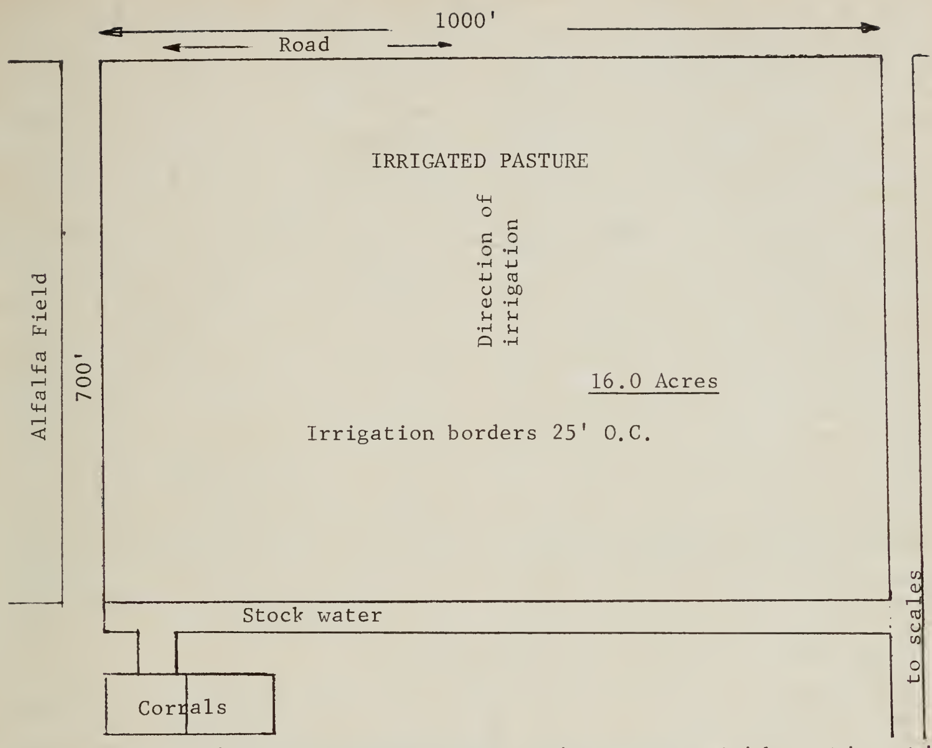


Fig. 1. General field layout for irrigated pasture studies. Fencing varied from trial to trial. Usually fences were 25 feet apart, placed upon the irrigation borders. In this case each field was 0.4 acre. When larger fields were necessary, four to six irrigation checks were placed into one field with the fencing again upon the irrigation borders.

moved, except during the last two years of the grazing trials when no fertilizer was used.

When alfalfa (*Medicago Saliva var. Calverde*) was grazed or harvested it was from an adjoining field and was watered monthly.

Before the start of the experiments, the first cutting of forage from each field was harvested and not used for the experiment. This was done to obtain the prescribed number of days regrowth on a field before the cattle were allowed to graze. The fields were again clipped the day the animals were rotated to another pasture. All chopping or clipping was performed by use of a flail-type forage harvester. The above was true for all years except the last two when no chopping or clipping was performed.

When sheep were used, they were mixed, good-choice crossbred western ewe and wether feeder lambs weighing approximately 70–80 pounds at the start of the studies. Before being allotted at random into lots of 20 head each, they were individually identified, treated for internal parasites, vaccinated for Blue tongue and contagious ecthyma (sore mouth). The beef animals used were yearling good–choice feeder steers usually weighing 550 to 650 pounds at the start of the trials. The animals were individually identified (number branded), vaccinated for infectious bovine rhinotracheitis (IBR), leptospirosis and treated for internal parasites when necessary. After an initial adjustment period each year of from three to six weeks, the steers were allotted at random, usually ten head per treatment, to the respective experimental lots. During the course of the

experiment all animals were weighed every 28 days after an overnight stand without feed or water.

When digestibility and food intake were determined, each lot contained three animals that had previously been trained for fecal collection purposes. The digestibility and feed intake was measured at three approximately equal intervals during each experiment. These determinations were made by administering a 20-gram capsule of chromium oxide orally at 7:00 a.m. daily during a preliminary period of seven days, and continuing for a six-to seven-day collection period during which grab samples of feces were collected from the rectum twice daily (7:00 a.m. and 5:00 p.m.). The digestibility and food intake was then determined in the laboratory as proposed by Reid *et al.* (1952) and Lofgreen *et al.* (1956).

Available forage was measured by the clipping technique. Before the animals entered a pasture, 5 to 10 areas of 18 square feet each were clipped at random, 2 inches high. Grab samples were taken from these clipped areas for dry matter and species determinations and others composited for chemical analysis. Because during the laboratory analyses a large percentage of silica was found in the forage samples, all results were calculated on a silica-free basis.

The comparative slaughter technique was used for determining main differences between treatments. For use of this slaughter technique, representative steers or sheep were slaughtered before the start of the experiment and at the end of the study or, in some trials, at the end of each period. Carcass data were then obtained on these animals. Specific gravity as described by Garrett *et al.* (1959) and Meyer *et al.* (1961) was used to estimate body composition. Corrected carcass weights and empty body weights were estimated by the methods proposed by Meyer *et al.* (1961) and by Lofgreen *et al.* (1962), respectively. Energy gained by the animals during the experiments was calculated by comparing initial and final carcass composition. The data were analyzed for variance and covariance, and Duncan's multiple range test (1955) was used to determine differences between treatments.

GRAZING MANAGEMENT

Management must consider not only the requirements of the plants but also of the animals and their interrelationships. One important aspect of maximum production from forage is the method selected for utilization of that forage by animals. Since the beginning of agriculture, pasturing has predominated. Haying was developed to serve the forage shortage caused by the winter season. Soiling was first useful where labor was inexpensive and land intensively farmed. Today, the development of labor-saving machines—the forage harvester and self-unloading wagon—revived the practice of soiling. Except for the commercial feedlot operator, who buys all of his feed, the beef producer has a feed supply that he must market by converting it to meat. The kind, quality, and quantity of feed supply, as well as the time of year it is available, determine the method of utilization and numbers of animals he should have to realize the greatest potential gain. It is, therefore, a constantly pressing problem to find ways of increasing efficiency of livestock operations when returns to the farmer per unit are steady or falling, and production costs are high. An irrigated pasture is an irrigated area with a satisfactory stand of seeded forage plants suitable for grazing by livestock. It may occasionally be mowed for hay, soilage (green chop), or to reduce weeds or coarse clumps; in general, however, it is used to produce the most pounds of meat per acre by grazing livestock.

TYPE OF FORAGE

Yields per acre of irrigated pasture vary considerably from month to month (figure 2) and from year to year. Furthermore, total yields for the year varies widely from farm to farm, depending on differences in soil, climate, cultural practices, species grown, and grazing management. Pastur-

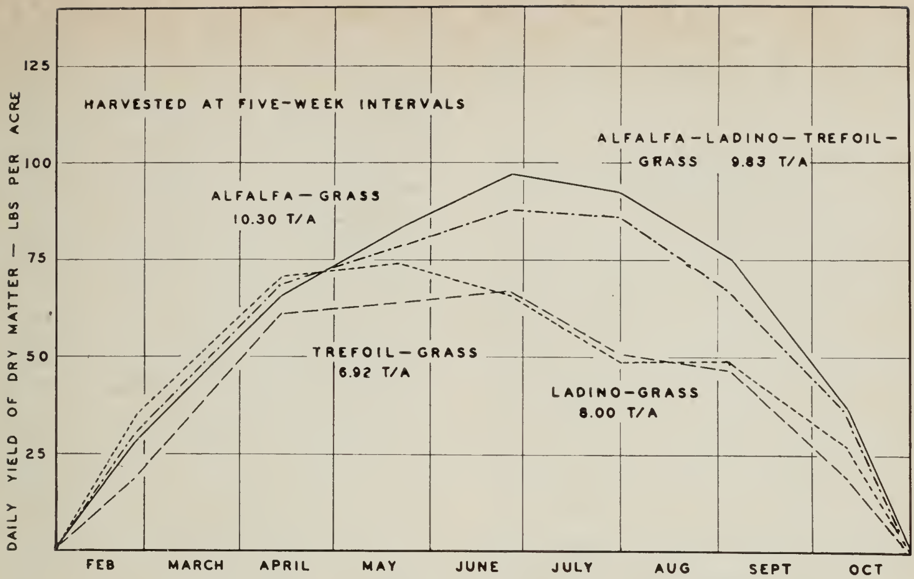


Fig. 2. Average seasonal forage growth for four different irrigated pasture mixtures when each was harvested at intervals of five weeks over the three-year period, 1949-1951 (Peterson and Hagan, 1953).

TABLE 1

EFFECT OF CUTTING FREQUENCY UPON THE BOTANICAL COMPOSITION OF FOUR IRRIGATED PASTURE MIXTURES AS DETERMINED BY HAND SEPARATIONS MADE IN JULY AND SEPTEMBER, 1950.
(Percentages on a dry-weight basis.)

Mixture	Component of mixture	Frequency of cutting in weeks							
		Two	Three	Four	Five	Two	Three	Four	Five
		per cent				*per cent*			
		July, 1950				September, 1950			
Broadleaf trefoil with grass..........	Trefoil	77.0	87.8	91.5	91.2	46.8	58.1	75.1	81.0
	Grass	22.7	10.5	7.7	8.8	50.0	38.6	23.5	19.0
	Misc.	0.3	1.7	0.8	0.0	3.2	3.3	1.4	0.0
Ladino clover with grass............	Ladino	79.9	84.7	87.8	90.0	56.5	69.6	77.6	79.1
	Grass	20.1	15.3	11.4	10.0	43.5	29.8	22.0	20.5
	Misc.	0.0	0.0	0.8	0.0	0.0	0.6	0.4	0.4
Alfalfa with grass..................	Alfalfa	71.7	88.2	93.7	96.5	44.1	65.6	87.7	95.8
	Grass	27.9	11.8	6.3	3.5	52.4	34.2	12.2	4.3
	Misc.	0.4	0.0	0.0	0.0	3.5	0.2	0.1	0.0
Alfalfa, ladino, and trefoil with grass	Alfalfa	6.1	15.9	67.0	94.2	1.1	8.3	70.5	87.4
	Ladino	72.8	66.7	23.7	1.8	58.1	57.4	14.4	4.0
	Trefoil	1.3	1.0	0.1	0.0	0.8	0.7	0.2	0.5
	Grass	19.8	16.4	9.2	4.0	40.0	33.6	14.9	8.1

Source: Peterson and Hagan, 1953.

age, however, is generally most abundant in late spring and early summer, when yields gradually decrease until the low level in winter.

The effect of cutting frequency upon botanical composition has been shown by Peterson and Hagan (1953). Table 1 shows that the percentage of grass present in September was approximately double the amount present in July. This is not surprising in view of the cool-season growth characteristics of tall fescue, orchardgrass and ryegrass. When alfalfa was the legume present in the mixture, it made a rapid recovery and more erect growth than ladino clover or trefoil. Trefoil in general is a poor competitor, especially in relation to other fast growing grasses or legumes.

REASONS FOR GRAZING MIXTURES

Even though a pasture mixture under optimal conditions yields only 80 per cent of that of alfalfa (figure 2), it is grazed much more frequently than alfalfa because bloat is a hazard for animals grazing immature alfalfa or a pasture containing a high percentage of legumes.

Several methods of prevention or control of bloat are presented in the review by Cole and Boda (1960): (1) Feed 3–5 pounds per head daily of dry roughage such as Sudan or oat hay to the grazing animal. (2) Mow strips and allow to wilt in the alfalfa field before turning the animals in to graze. (3) Let the alfalfa reach the full bloom stage before pasturing. (4) Cut alfalfa for soilage and let it wilt before feeding. (5) Keep at least 50 per cent of the grazed mixture grass or legumes that do not produce bloat, such as birdsfoot trefoil. (6) Spray the field to be grazed with mineral oil. These are not all of the ways of preventing bloat nor are they 100 per cent effective for grazing animals but they will aid in cutting down the incidence of bloat. Another reason for grazing a mixture is to take advantage of the seasonal growth characteristics of both grasses or legumes; as previously mentioned, some will grow better under long hot days and some under the cooler shorter days. Alfalfa is also unsuitable on shallow and marginal land. We therefore recommend that mixtures of grasses and legumes be grazed and alfalfa be grazed only during its semidormant period (late October to mid-February).

Table 2

ALFALFA VS. PASTURE MIXTURE – STEERS VS. LAMBS

Item	Alfalfa pasture	Trefoil-orchardgrass pasture
Beef Steers		
Average daily gain, pounds	1.66	1.75
TDN content of forage dry matter consumed	60.7	66.4
Feed per pound gain, pounds	11.8	12.9
Average terminal carcass grade	standard	high standard
Beef produced per acre, pounds	447	359
Beef produced as per cent of alfalfa	100	80
Feeder Lambs		
Average daily gain, pounds	0.34	0.31
TDN content of forage dry matter consumed	66.1	67.4
Feed per pound gain, pounds	7.9	9.1
Average terminal USDA carcass grade	choice	choice
Lamb produced per acre, pounds	440	388
Lamb produced as per cent of alfalfa	100	88
Forage		
Yield per acre, dry matter, pounds	8,300	5,100
Per cent yield of alfalfa	100	62
Per cent dry matter consumed by cattle	59	82

TYPE OF ANIMAL

Grazing cattle and sheep respond differently, as illustrated in table 2, showing carcass grade and animal response. The response also differs, depending upon the type of forage grazed.

The TDN content of the trefoil-orchardgrass pasture consumed by sheep and cattle was about the same (table 2). However, from the alfalfa pasture, the sheep selected a diet with a higher TDN content than the steers. The interaction of animal species and method of feeding was statistically significant. An important degree of selection was exhibited, however, by the steers on alfalfa pasture. The TDN content of forage consumed by cattle illustrates selective grazing on alfalfa, but with lower-growing, dense forage, selective grazing is not manifested or, at least, TDN does not measure differences. The type of forage to be utilized should therefore determine the type of animal to graze.

Selective grazing, resulting in refusal to eat coarse alfalfa stems, together with the higher TDN of the trefoil-orchardgrass, tended to narrow the importance of differences in yield between alfalfa and trefoil-orchardgrass. Table 2 also shows that trefoil-orchardgrass produced 62 per cent of the dry matter produced by alfalfa. The steers, however, produced 80 per cent as much meat from an acre of trefoil-orchardgrass as they did from alfalfa even though alfalfa produced a greater yield of dry matter. An even greater utilization (88 percent) was made by sheep. Yield of forage dry matter, therefore, does not correctly appraise its value for animals. The final analysis will always have to be with animals as the measuring unit.

Utilization of the grazed forage by sheep or cattle occurred to a different degree as shown by slaughter grades (figure 3). The number of steers given trefoil-orchardgrass which graded in the "good" slaughter grade was greater than the number grazing alfalfa. The lambs, however, reached a "choice" slaughter grade when allowed to graze. It was also found that the lambs consuming trefoil-orchardgrass attained a "choice" slaughter grade in fewer days than the lambs grazing alfalfa.

In general, it appears that sheep are superior to steers in their ability to utilize pasture. This was borne out by daily gains, feed consumption, efficiency of feed utilization and type of gain on pasture.

DAILY RATION VS. WEEKLY ROTATION

The method where animals receive their forage in a long narrow strip, as if it were offered to them in a long manger or feed bunk, is called daily-ration or strip grazing. This method reduces trampling losses to a minimum, and feces and most of the urine falls on an area which has already been grazed. This type of grazing was compared to rotational grazing where animals grazed a field from six to ten days. Tables 3 and 4 give the comparisons. Decreasing the grazing interval increased production per acre. However, it did not appear practical to reduce the grazing interval to less than six days. Even the intensive strip grazing method where fresh forage was given daily was little better than a six-day rotational grazing interval. It was concluded that, depending upon feed supply and the necessary irrigation cycle, rotating the cattle every five to seven days to a new field would give near optimum beef per acre from grazing.

RECOVERY INTERVAL

Studies were conducted during two pasture seasons on the effect of forage recovery intervals of 24, 30 and 36 days. The stocking rate was held approximately equal in all treatments to obtain the same degree of grazing intensity. Both animal response, forage yield, and botanical composition data were obtained.

The data indicated that the forage was grazed when in a vegetative stage (figure 4). No large differences were noted in TDN, crude protein, and lignin content of the grazed forage. Recovery interval of the forage did not influence steer response as measured by daily gain, feed consumption, efficiency of feed utilization, liveweight, dressed weight or energy gain per acre (table 5). Even though there appears to be a tendency for lowered production on the 36-day interval, these differences are not statistically significant. It may be, therefore, that with the type of pasture studied in these trials, a 36-day recovery period is

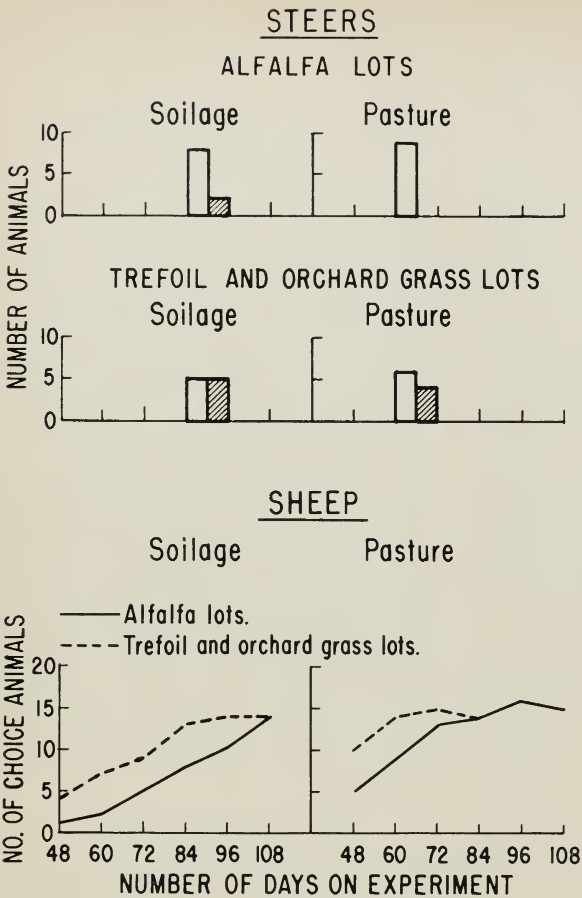


Fig. 3. Slaughter grades of the animals. Upper graph: The blank bars indicate number of steers graded "standard" at the end of the experiment, the cross-hatched bars represent the number graded "good." Lower graph: The sheep were graded in each weight period, and the number of animals in the "choice" grade are shown. The remaining sheep were graded as "good."

TABLE 3

BEEF PRODUCTION PER ACRE FROM ALFALFA FOR GRAZING STEERS

Year	Days	Rotational grazing			Strip grazing
		10-day	6-day	1-day	
		pounds per acre			
1952....	168	417	...	580	...
1953....	155	...	525	539	...
1954....	132	...	689	...	739

TABLE 4

EFFICIENCY OF TDN UTILIZATION FOR GAIN IN WEIGHT BY STEERS

Item	Rotational grazing	Strip grazing
TDN in forage, per cent.......	57.8	57.7
Daily gain, pounds............	1.73	1.54
Daily TDN consumed, pounds	8.7	8.0
Gain per 100 pound TDN consumed, pounds..........	20.1	19.3

approaching the interval which will allow the forage to become too mature for optimum utilization. When the type of forage studied in these trials is grazed at a vegetative stage, factors other than animal response may determine rotational intervals within 24 to 36 days.

STOCKING RATE

Stocking rate is one of a pasture operator's most powerful tools for controlling production from irrigated pasture on per-acre basis. Blaser *et al.* (1962) has stated that grazing by animals influences pastures in

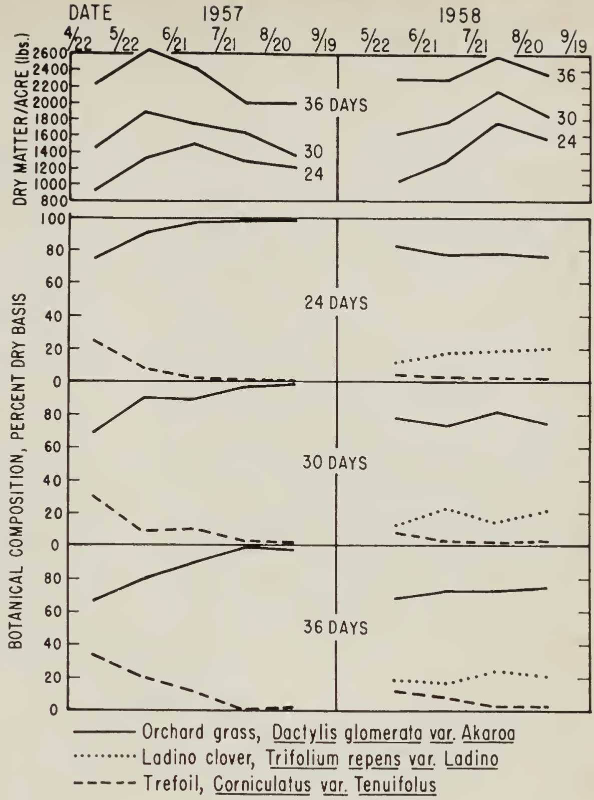


Fig. 4. Daily yield of dry matter and botanical composition of pasture as influenced by recovery interval.

TABLE 5

EFFECT OF RECOVERY INTERVAL ON DAILY GAINS, FEED CONSUMPTION AND CARCASS GRADE BY STEERS

Item	1957			1958		
Recovery interval of forage, days	24	30	36	24	30	36
Number of animals per treatment	6	7	8	10	12	14
Number of animals per acre	2.8	2.8	2.8	2.3	2.6	2.6
Duration of trial, days	142	142	142	120	120	120
Initial body weight, pounds	642	631	628	541	539	518
Daily body weight gain, pounds	1.52	1.52	1.46	1.61	1.56	1.42
Daily dry matter consumed, pounds per head	22.1	20.3	20.4	20.1	18.6	19.4
Daily TDN consumed, pound per head	14.7	13.2	13.0	12.9	12.1	12.4
Weight gain per pound of dry matter, pounds	6.9	7.5	7.2	8.0	8.4	7.3
Dressing percentage	58.4	57.7	57.7	53.2	54.2	54.4
Carcass grade, per cent of animals in grade:						
Good	0	14	0	0	0	0
Standard	83	86	88	90	100	100
Utility	17	0	12	10	0	0

at least four ways: total seasonal yields, longevity of plant species, botanical composition, and physiological stage of growth.

From our previous results a seven-day grazing period followed by a 35-day recovery between grazings was practiced. Equal stocking rates were obtained each year on the fields by using the same number of animals in the same size area for the entire season. Here again, forage data and animal response were obtained at different stocking rates.

The influence of the different stocking rates on the forage produced per acre daily as determined by pregrazing clippings at a height of 2 inches is shown in figure 5. The uniformity of the pasture at the start of these trials is demonstrated by the amount of forage available to the animals before they grazed—no differences were found in the initial sampling before the first grazing in 1959. In the subsequent grazings, treatment effects were evident, especially at the time of the third grazing. It is important to realize that even though heavier stocking rates decreased the yield of forage as the season progressed in each of the four years, the first cutting at the time of first grazing the following year showed no effects of the previous year's treatment (figure 6). This observation may indicate that the 35-day recovery interval was sufficient to maintain plant vigor and root reserves. It should also be noted that the pastures were not grazed during the winter months. These two factors could be among the most important factors in avoiding harmful effects of heavy grazing in well established pastures.

At the start of the experiment the mixture was composed of approximately 50 percent each of grass and legumes which has been considered, over the years, as the optimum proportions for a grass-legume pasture mixture. As the season progressed, a marked increase in the percentage of

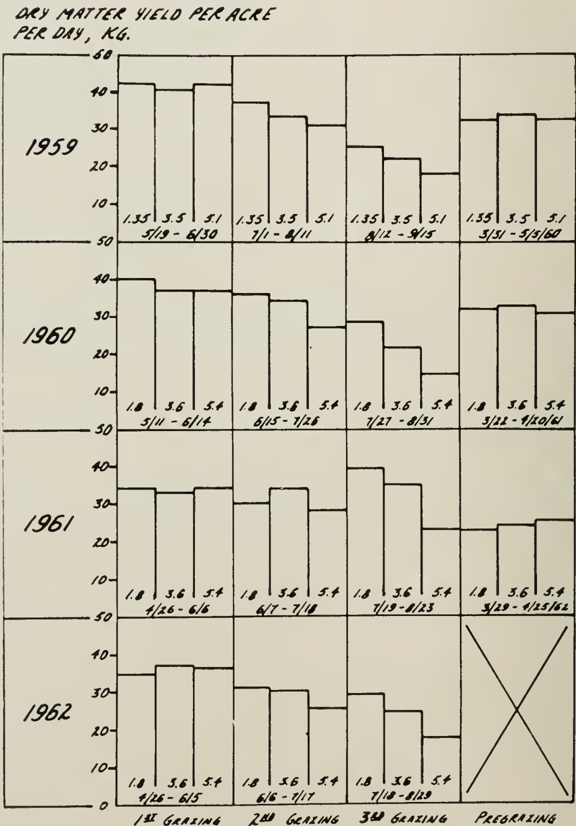


Fig. 5. Influence of stocking rate (1.35, 3.5, 5.1 steers per acre for 1959, and 1.8, 3.6, 5.4 steers per acre for 1960–1962) on forage produced per acre daily, as determined by clipped sample.

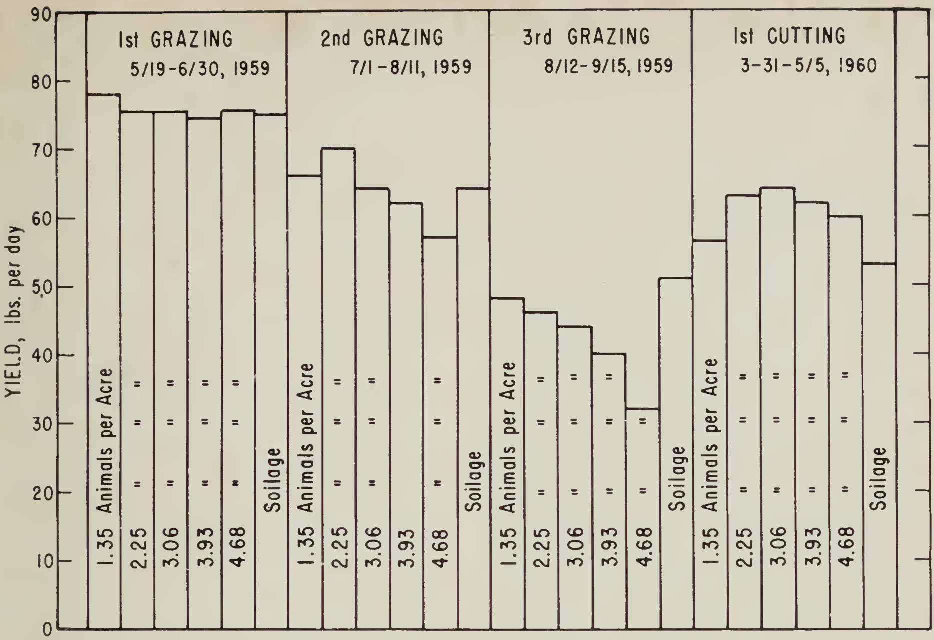


Fig. 6. Forage produced per acre daily, as determined by pregrazing clipping at a height of 2 inches.

grass was realized, and the same thing happened the following year. But during the third and fourth years of the trial, the grass tended to be constant and dominant at a high percentage. From these observations it can be said that heavy grazing favors legumes, as they reached this point more slowly, while light grazing tends to favor grasses. It could also possibly be said that orchardgrass resists better the effects of grazing and that it is able to remain longer in a good stand, or that ladino clover is more damaged by grazing and tends to disappear faster from the mixture. Any conclusions, however, also have to consider that nitrogen fertilization was employed, and this favors production of grasses and depresses, in the long run, the production of legumes.

The response of the steers was markedly influenced by stocking rate (table 6). The average daily gains per steer and the energy gain per head clearly show the effect of increasing the stocking rate on a per-head basis. In pasture experiments, maximum production per animal is not always the proper measurement. Production per acre may result in a more realistic evaluation. This is exemplified by the energy gain per acre which increases from

Table 6

STEER RESPONSE TO STOCKING RATE
(Average for 3 years)

Item	Stocking rate		
	Light	Medium	Heavy
Animals carried per acre	1.35	3.5	5.1
Number of animals	24	24	36
Number of days	124	124	124
Initial weight, pounds	610	613	628
Final weight, pounds	785	743	704
Average daily gain, pounds	1.41	1.06	0.62
Average D.M. consumed per head per day, pounds*	17.6	14.4	12.2
Average carcass weight, pounds	451	407	387
Final carcass fat, per cent	14.2	11.5	9.9
Energy gain per acre, megcals	327	385	182
Energy gain per head, megcals	237	110	36

* Average for only two years.

TABLE 7

EFFECT OF STEERS CARRIED PER ACRE ON IRRIGATED FORAGE*

Item	Stocking rate, head per acre				
	1.35	2.25	3.06	3.93	4.68
Average daily gain, pounds	1.81	1.72	1.44	1.31	0.80
Corrected carcass per acre, pounds	250	375	410	425	350
Gain per 100 pound feed, pounds	10.7	11.9	10.4	10.3	6.1

* Length of trial—126 days.

the light stocking rate to the medium stocking rate and then markedly decreased. The increase in production per acre up to 3.5 head per acre is explained by the fact that the animals harvested more of the forage even though consumption per animal decreased. The maximum consumption per acre was not the most desirable (5.1 head per acre) because the liveweight gain, energy gain per animal, and energy gain per acre decreased sharply as most of the forage consumed was for maintenance rather than gain.

A pasture operator would not know the feed intake of his steers but would be interested in knowing the point where feed intake per animal decreases and negates the advantage of having a larger proportion of the forage consumed per acre. In our trials (table 7), increasing the stocking rate to the point where daily gains did not go below 1.31 pounds per day provided the maximum production per acre. From figure 7, a plateau in carcass gain per acre occurred between 2.25 and 4 head per acre. This wide range of stocking rates gives about maximum production, thus providing the pasture operator with a range in which to maneuver his management practice.

It was concluded that a light stocking rate in the spring and a heavy one later in

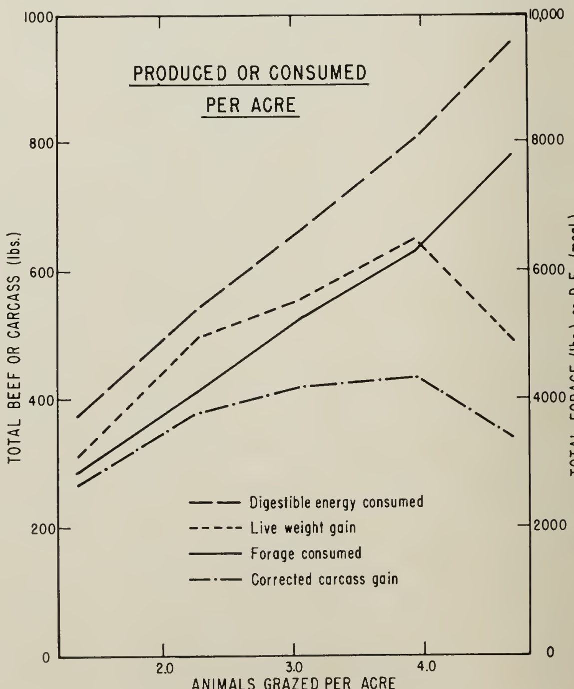


Fig. 7. Influence of stocking rate on production or consumption per acre as determined by steers.

the season, as related to forage growth, would give maximum production of beef from the irrigated pasture throughout the season. The reason for this is that cattle at the lighter stocking rates in relation to forage growth would contain more fat in their weight gain whereas at the heavy stocking rates more animals are carried per acre, again in relation to forage growth, but their weight gain contains less fat. Thus weight gain per head and gain per acre would be equal for their respective parts of the grazing season.

CONTINUOUS VS. ROTATIONAL GRAZING SYSTEM

The controversy regarding continuous or rotational systems of grazing management appears to be far from settled. The species of plant used and the type of animal grazed may be as important as the type of grazing management practiced. There is evidence that rotational grazing may be advantageous over continuous grazing at high stocking rates.

Because of the interaction between method of grazing and stocking pressure, an experiment was designed to compare rotation and continuous grazing with beef steers where (1) stocking rate was not limiting and (2) where higher than optimal grazing pressure was achieved by (a) a higher than normal stocking rate well within the season of adequate forage production, and (b) an optimal stocking rate with the grazing season extended beyond the period of adequate forage production. This experiment was conducted for each of three years.

Plant cover and botanical composition were determined during the final year of the experiment. The treatments were: (1) six-field rotational grazing, (2) two-field continuous grazing. Both management systems were studied at: (a) *medium* stocking rate and grazing pressure over the season of rapid forage growth, (b) *heavy* stocking over the season of rapid forage growth, (c) medium stocking over the season of rapid forage growth and adjusted so the forage would not be limiting when the

TABLE 8

STEER RESPONSE TO GRAZING SYSTEM AND PRESSURE

(Average for three years)

Item	Rotational grazing‖			Continuous grazing‖		
	Grazing pressure			Grazing pressure		
	Medium	Heavy	Extended	Medium	Heavy	Extended
Animals carried per acre*†	2.9	4.4	2.9	2.9	4.4	2.9
Animal days grazing	918	1,356	1,121	820	1,113	1,023
Average daily gain, pounds	1.14^{cd}	1.02^{b}	1.16^{cd}	1.52^{ab}	1.28^{b}	1.63^{a}
Initial weight, pounds	561^{a}	571^{a}	568^{a}	579^{a}	548^{a}	558^{a}
Final weight, pounds	728^{c}	709^{c}	779^{b}	798^{ab}	708^{c}	839^{a}
Carcass data:						
Final weight, pounds	387^{c}	373^{c}	424^{f}	446^{b}	385^{c}	488^{a}
Dressing percentage	53.2^{d}	52.5^{d}	54.9^{c}	55.9^{b}	54.9^{c}	58.0^{a}
Fat, per cent	11.7^{cd}	10.0^{de}	12.6^{bc}	13.7^{ab}	9.5^{c}	15.0^{a}
Protein, per cent	19.1^{bc}	19.4^{ab}	18.0^{cd}	18.78^{cd}	19.6^{a}	18.3^{d}
Fat corrected carcass, pounds	302^{cd}	268^{d}	332^{bc}	367^{b}	272^{d}	422^{a}
Final carcass grade‡	3.4^{d}	2.6^{f}	3.8^{c}	4.4^{b}	3.3^{e}	4.8^{a}
Marbling score§	2.7^{c}	2.3^{d}	3.2^{b}	3.4^{b}	2.5^{cd}	3.8^{a}
Backfat thickness, inches	0.24	0.24	0.22	0.33	0.21	0.37
Ribeye area, square inches	8.8	8.5	9.1	9.2	8.8	9.9
Energy gain, megcals	194^{cd}	128^{d}	253^{bc}	308^{ab}	154^{d}	399^{a}

* Initial stocking rates only.
† 2.16 acres per treatment.
‡ 3 = standard, 6 = good, USDA grades.
§ 2 = practically devoid, 3 = traces, 4 = slight, USDA scores.
‖ a, b, c, d, e, f. Means on the same line having the same superscript do not differ significantly $P < .05$.

grazing was *extended* into the season of slow forage growth.

When grazing systems are compared, large differences are apparent in animal days grazing (table 8). These differences have special significance as the steers on the continuously grazed treatments occasionally had less feed available than was necessary for maintenance. These lots therefore were supplemented with alfalfa hay. Gains due to alfalfa hay were not credited to the trial. As the stocking rate increased 32 percent from the medium to the heavy, the continuously grazed treatments were supplemented 98 and 243 days respectively, depending upon stocking rate. The rotationally grazed animals also had less than maintenance amounts of feed available at various times during the grazing season but this lack of forage occurred only when one or two days remained before they were to be moved to another field with adequate forage available. They therefore were not supplemented. This factor of supplementation, as reflected in animal days grazing, would be quite important when determining what type of grazing system a pasture operator should use.

Significant differences were found in the average daily gain (table 8). These differences depended upon grazing pressure and were in favor of the continuously grazed steers. This increase in daily gain, as reflected by final weight, may or may not be of advantage depending upon the size of the animal desired at the end of the grazing season. Under either system of grazing management the steers were of feeder grade with undesirable finish for slaughter grade, as shown by carcass data.

Extending the grazing season, especially under continuous grazing, markedly increased energy gain and liveweight gain per unit area (table 9). It should be noted that liveweight gain per acre does not give the magnitude of difference that energy gain per acre demonstrates.

An interaction between beef production, stocking rate, and grazing system was observed. Medium grazing pressure was better than heavy grazing pressure for both systems but not as good as extended grazing for the continuous system. When grazing systems are compared on an energy basis, extended grazing definitely was greatest for continuous grazing and under this system heavy stocking pressure definitely was not favorable.

It appears that rotational grazing would yield the most per-unit area when stocked heavier than that which would give optimum animal daily gains, and that, to obtain maximum production per unit area under continuous grazing, it should be stocked for optimum daily gain per individual. Final livewight gain would also be a criterion in determining the grazing system to practice.

An additional aspect of these trials was the influence of grazing management system upon plant species (table 10). The grazing management systems allowed a

TABLE 9

RELATIVE COMPARISONS OF GRAZING SYSTEMS AS DETERMINED BY GRAZING STEERS

(Highest treatment set at 100 per cent)

Item	Rotation grazing			Continous grazing		
	Grazing pressure			Grazing pressure		
	Medium	Heavy	Extended	Medium	Heavy	Extended
	per cent (Highest treatment set at 100 per cent)					
Animal days per acre	68	100	83	60	82	68
Live weight gain per acre	65	79	79	76	70	100
Live weight gain per acre per animal day	65	54	65	86	57	100
Energy gain per acre	48	46	61	71	48	100

TABLE 10
PER CENT OCCURRENCE OF PLANT SPECIES DURING THIRD YEAR OF GRAZING

Plant species	Rotation grazing Grazing pressure			Continuous grazing Grazing pressure		
	Medium	Heavy	Extended	Medium	Heavy	Extended
	per cent					
Grasses						
Orchardgrass	52.4	47.6	47.7	43.7	44.2	27.3
Rye grass	10.1	9.7	8.6	20.1	21.2	25.5
Fescue	27.5	16.1	25.0	5.6	4.8	1.7
Total	90.0	73.4	81.3	69.4	70.2	54.5
Legumes						
Ladino clover	3.7	13.9	10.2	10.8	6.9	13.3
Strawberry clover	2.8	4.3	4.5	14.3	15.9	27.0
Total	6.5	18.2	14.7	25.1	22.8	40.3
Weeds, etc.	3.5	8.4	4.0	5.5	1.0	5.2

marked shift in botanical composition to occur. In general, a higher proportion of legumes was maintained in the heavily grazing treatments. The continuous treatments also seemed more desirable as far as the height of the sward was concerned, resulting in the sward being maintained in a more vegetative condition, therefore in a more productive state. In addition, the rotationally grazed pastures were more susceptible to invasion by tall fescue which was not utilized as well as the other grasses. There seemed to be a need for more frequent irrigations for the continuous grazed areas. The heavy grazing pressure under rotation grazing did not seem to hurt the sward but this may have been because of the 35-day enforced recovery period which allowed the plants to recover from an oppressive stocking rate.

In general, when choosing a grazing management system, several criteria should be taken into consideration, such as grazing season, type of forage, type of animal, stocking rate, recovery interval desired, and whether to use continuous or rotational grazing. Different methods of utilization and management must result in a compromise between plant and animal relationships.

GRAZING BEHAVIOR

DAY IN THE FIELD

A knowledge of the behavior of grazing animals is important to a complete understanding of productive performance. Correlation of these behavior patterns to their productive performance on various types of forages is also important.

A series of 24-hour observations were made on both sheep and cattle grazing alfalfa or trefoil-orchardgrass pastures. These observations were made starting at noon on the second day in a new field and terminating at noon of the third day. A second 24-hour observation was started at noon of the fifth day in the field and terminated at noon on the sixth. For convenience, these two observations are referred to as the second and fifth day. Their purpose was to determine possible changes in behavior when animals are grazing abundant, compared to scant, forage. The

TABLE 11

BEHAVIOR PATTERNS OF STEERS AND LAMBS EATING ALFALFA AND TREFOIL ORCHARDGRASS FORAGE

Pasture	Eating green forage		Eating hay		Ruminating	
	Steers	Sheep	Steers	Sheep	Steers	Sheep
	hours					
Alfalfa:						
Second day in field	6.1	6.9	1.5	0.2	4.4	3.1
Fifth day in field	7.9	10.1	1.0	0.2	7.7	3.4
Trefoil-orchardgrass:						
Second day in field	6.7	8.6	0.7	0.2	5.9	4.5
Fifth day in field	6.4	9.0	0.8	0.5	7.7	4.4

size of the fields were adjusted so that forage would be well utilized at the end of six days.

The average amount of time spent eating green forage, eating hay, and ruminating in a 24-hour day is shown in table 11. Changes in the time spent grazing and that spent ruminating are shown by hourly intervals in figure 8. Ruminating time includes both standing and lying.

There are a number of interesting effects noticeable from these data. Both steers and sheep spent more time grazing on alfalfa pasture the fifth day in the field than they did on the second day. This is shown in figure 8 by the increase in the amount of time spent grazing per hour during grazing, and also in the case of the steers, by the increase in the number of hours during which some animals were grazing. On trefoil-orchardgrass pasture, however, there was no difference in grazing time between the second and fifth days. The difference in the grazing pattern of steers and sheep on alfalfa pasture is interesting. The periods of grazing were more definite with steers than with sheep. This is particularly noticeable on the second day where some sheep were grazing well into the night while steers grazed only during one hour after dark. The difference between steers and sheep in the time spent ruminating is important. On both alfalfa and trefoil-orchardgrass the steers spent more time ruminating the fifth day than on the second. The reason for this is the increased time spent per hour—the time of day during which ruminating occurred did not change (figure 8). The sheep, however, ruminated the same length of time each of the two days, and the pattern of time spent ruminating the two days was similar. Steers spent more time ruminating on both days than did the sheep.

The TDN content of the forages as determined is a measure of the average digestibility of the forage over a given six-day period (table 12). Because of the close relationship, however, of the ruminating time (RT) to eating time (ET) ratio to TDN of alfalfa forage, an opportunity is provided to estimate the changes in TDN of alfalfa forage selected on the second and fifth days on a pasture (table 13). By use of the regression equation.

$$Y = 8.3 - 0.12X \ (r = -0.89, S_{Y \cdot X} = 0.14)$$

and the ratios of 0.72 and 0.97 for steers on alfalfa pasture it is estimated that they consumed a forage containing 63.3 and 60.8 per cent TDN on the second and fifth days, respectively. The sheep, on the other hand, showed little difference in the RT/ET ratio between the second and fifth days on either alfalfa or trefoil-orchardgrass pasture table 14). It can be concluded therefore, that the sheep, but not the steers, even on the fifth day in the field were able to select forage of high digestibility. The differences in behavior pattern on the two types of forage seems to be related to the ability of the animals to graze selectively.

SELECTIVE GRAZING

As mentioned, the variations between sheep and cattle in utilization of forage

TABLE 12

RELATIONSHIP OF DRY MATTER AND TDN CONSUMPTION TO TIME SPENT EATING FOR STEERS AND LAMBS

Animal	Alfalfa			Trefoil-orchardgrass		
	Dry matter consumed	TDN consumed	Eating time	Dry matter consumed	TDN consumed	Eating time
	pounds	*pounds*	*hours*	*pounds*	*pounds*	*hours*
Steers	14.6	8.9	7.0	19.0	12.6	6.6
Sheep	2.36	1.56	8.5	2.70	1.82	8.8

TABLE 13

RATIO OF RUMINATING TIME (RT) TO EATING TIME (ET) THE SECOND AND FIFTH DAYS IN A FIELD FOR STEERS AND LAMBS

Pasture	RT/ET	
	Steers	Sheep
Alfalfa:		
Second day	0.72	0.45
Fifth day	0.97	0.34
Trefoil-orchardgrass:		
Second day	0.88	0.52
Fifth day	1.20	0.49

TABLE 14

RELATIONSHIP OF DIGESTIBILITY TO THE RATIO OF RUMINATING TIME (RT) TO EATING TIME (ET) FOR STEERS AND LAMBS

Animal	Alfalfa		Trefoil-orchardgrass	
	TDN	RT/ET	TDN	RT/ET
	per cent		*per cent*	
Steers	60.7	0.85	66.4	1.04
Sheep	66.1	0.40	67.4	0.51

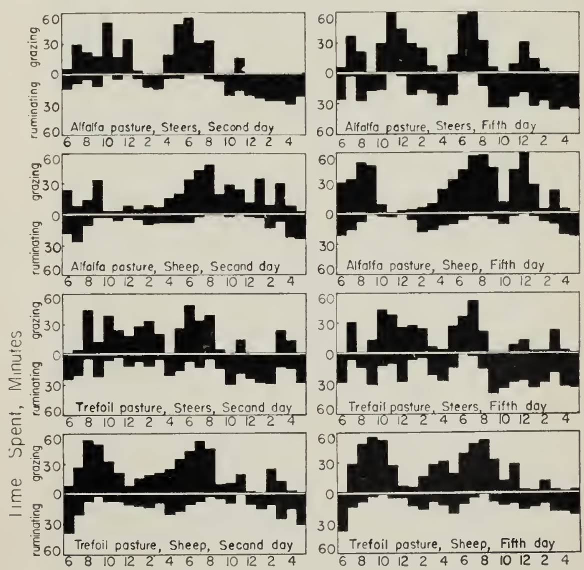


Fig. 8. Grazing behavior of steers and sheep as influenced by type of pasture and day in the field.

Fig. 9. Above: The refused alfalfa left after six days grazing by steers.

Fig. 10. Left: The refused alfalfa left after six days grazing by sheep.

are based on differences in abilities to select forage.

The TDN content of the trefoil-orchardgrass pasture consumed by sheep and cattle was the same. However, in the alfalfa pasture the sheep selected a diet which had a higher TDN content than that selected by steers. The interaction of animal species and method of feeding was statistically significant. An important degree of selecttion was exhibited, however, by the steers on alfalfa pasture as evidenced by the 60.7 per cent TDN compared to 66.4 per cent TDN in trefoil-orchardgrass pasture (table 14).

Superior selective grazing ability of the sheep compared to the steers is also demonstrated in comparing figures 9 and 10. The remaining forage from the steer alfalfa pasture exhibits more leaves unconsumed than those left by sheep. It was very apparent throughout the trial that very few leaves were missed during grazing by the sheep whereas the steers did not seem to attempt or were unable to select as many leaves.

Another indication that sheep did more selecting than cattle is contained in the fact that sheep consumed much less dry matter from one acre in all treatments than steers (table 15). This was particularly true for the sheep grazing the alfalfa pasture. The increased TDN content of the alfalfa forage selected by the sheep was not enough, however, to compensate completely for the lowered dry matter intake. The sheep, therefore, consumed less TDN than the steers from alfalfa pasture. However, they produced as much meat per acre as did the steers. The data also show that the sheep made a fattening gain while the steers did not. Even though the gain of the sheep probably contained more energy because of their finished condition, more meat was produced per 100 pounds of TDN consumed by sheep on alfalfa pasture than steers on the same treatment (table 15). In other words, the TDN selected by the sheep contained more net energy than the TDN selected by the steers.

In general the trefoil-orchardgrass forage consumed contained more TDN than the alfalfa forage (table 15). There was one exception. The sheep on alfalfa pasture did a superior job of selection and actually consumed an alfalfa forage with as high a TDN as that consumed from the trefoil-orchardgrass pasture. The interaction of method of feeding and plant species was statistically highly significant which gives weight to this evidence. Table 15 also shows that the gain for the sheep per 100 pounds of TDN consumed from alfalfa pasture was larger than the gain by the sheep on trefoil-orchardgrass pasture.

Selective grazing which resulted in refusals to eat coarse alfalfa stems together with the higher TDN of the trefoil-orchardgrass tended to narrow the importance of differences in yield between alfalfa and trefoil-orchardgrass. Table 15 shows that trefoil-orchardgrass produced 58 to 63 per cent of the dry matter produced by alfalfa. The steers, however, produced 80 per cent as much meat from

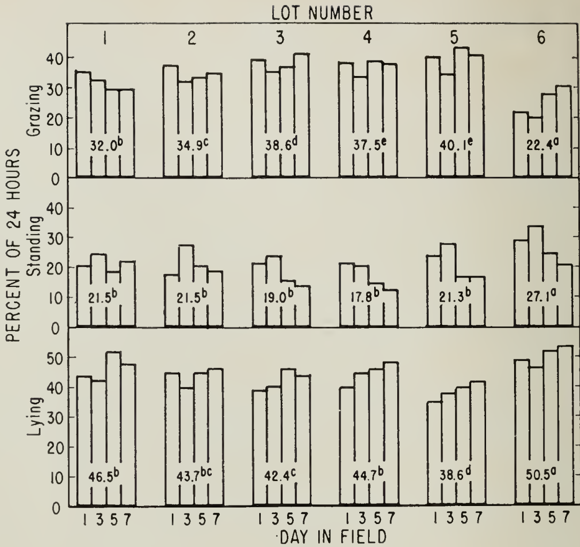
Table 15

COMPOSITION OF FORAGE DRY MATTER AND TOTAL DIGESTIBLE NUTRIENTS*

Pasture	Steers				Sheep			
	Dry matter available	Dry matter consumed	TDN consumed	Gain/100 pounds TDN consumed	Dry matter available	Dry matter consumed	TDN consumed	Gain/100 pounds TDN consumed
	pounds per acre				*pounds per acre*			
Alfalfa........	2,711	1,612	978	14.3	2,691	1,252	832	19.3
Trefoil-orchardgrass...	1,567	1,389	921	11.9	1,437	1,345	906	16.4

* Average consumption during three collection periods.

Fig. 11. Behavior of steers grazing irrigated pasture at various stocking rates (1.35, 2.25, 3.06, 3.93, 4.68 steers per acre) for lots 1 through 5, respectively, and time spent eating soilage for lot 6. Values with different superscript letters are significantly different.



one acre of trefoil-orchardgrass as they did from alfalfa even though alfalfa produced a greater yield of dry matter. An even greater utilization was made by the sheep. The sheep produced 89 per cent as much meat per acre from the trefoil-orchardgrass as from the alfalfa.

Yield of forage dry matter, therefore, will not correctly appraise its value for animals. The final analysis will always have to be with the animal as the measuring unit. Even here a great deal of caution needs to be exercised because of differences in the composition of weight gains and possible influence of improper weighing conditions if the animals are not shrunk before weighing.

It is concluded, therefore, that selective grazing is more apparent and to a higher degree on a tall, sparse-growing plant than on a low, dense forage plant. Sheep are also more selective than cattle.

STOCKING RATE

Grazing intensity or stocking rate has an influence on animal performance as previously stated. The stocking rate can also have an influence on grazing behavior. Figure 11 shows that as stocking rate increases grazing time increases but only up to a point. As the stocking rate was progressively increased from 1.35 to 3.06 head per acre, significantly more time was spent grazing and less time standing or lying because, no doubt, competition for forage became greater as grazing intensity increased.

As the stocking rate increased from 3.06 to 4.68 head per acre, the time spent grazing did not increase significantly, but the time spent lying did. It therefore appears that an animal will only spend so much time grazing (approximately 10 hours per day) even if forage available is below its needs.

SOILAGE

Soiling (green chopping) the cutting and hauling of green forage to livestock has been practiced for many years. Its main use, however, has been to supplement pasture during periods of limited feed production. At such times some high-yielding crop has been grown specifically for soiling purposes. Depending upon the type of pasture

Table 16

DAILY GAINS AND FEED UTILIZATION FOR STEERS USING DIFFERENT HARVESTING METHODS

Item	Six day rotational grazing	Strip grazing	Soiling	Haying
		1954 (132 days)		
Daily gains, pounds	1.62	1.42	1.40	1.13
Feed consumption, pounds	13.9	12.8	15.0	19.0
Gain per 100 pounds of feed	11.7	10.0	9.3	5.9
Beef production per acre, pounds	689	739	1,080	856
		1956 (108 days)		
Daily gains, pounds	1.65	....	1.34	....
Feed consumption, pounds	19.2	....	23.0	....
Gain per 100 pounds of feed, pounds	8.6	....	5.8	....
Beef production per acre, pounds	447	....	563	....

and the crop available for soiling, the economy of such a program varies considerably. It has usually been true that the cost of soiling has limited the practice. Recently, however, interest has been revived, particularly in the alfalfa-growing regions of the West, where soiling has been used to replace, rather than supplement pasturing. The use of modern labor-saving forage harvesting and self-unloading wagons may make soiling an economical replacement for pasturing.

SOILAGE VS. HAYING OR PASTURING

Since alfalfa is California's most important and highest yielding irrigated forage crop, this forage was considered for use as soilage. The alfalfa was fed as hay, pasture or soilage. Of the various methods studied, soilage produced the greatest beef production per acre from alfalfa followed by haying and pasturing in that order (table 16).

SOILAGE FOR SHEEP

As noted, sheep will reach an acceptable slaughter grade on pasture earlier than cattle. This is attributed to the selective grazing ability of the sheep resulting in a very nutritious forage consumed. This is no longer apparent to such a degree when soilage is fed. For lamb feeding, green chop alone cannot be expected to replace a hay and grain mixture because of lack of adequate feed consumption and/or selection by the animals. It would also be advisable to feed grain in with the soilage unless the forage is fed several times a day. The dry matter of the soilage is extremely variable, usually about 8 to 25 per cent, depending on the stage of maturity and weather conditions when the forage is harvested; also forage species composition will have an effect. Crude protein is usually above 15 per cent unless the forage is quite mature. The TDN is commonly 65 to 70 per cent on a dry basis or about halfway between that of a good hay and grain. This is higher than it would be from hay made from the same pasture, partly because hay is often cut at a later stage and partly because nutrients are lost during the curing process, particularly under most haying conditions. The high moisture will heat the soilage in the feed bunks; thus, for sheep fresh soilage should be furnished at least two times per day. If soilage is fed to sheep, it should be used for feeding groups of ewes or other sheep not on a fattening diet. When either alfalfa or trefoil-orchardgrass forage was fed as soilage, there was no difference in the TDN content of the forage consumed by either sheep or cattle (table 18). Apparently neither species was able to select out a highly nutritious diet but consumed all of the harvested plant. In the case of sheep, their nutrient intake was not great enough to produce a fattening gain.

TABLE 17

EFFECT OF FORAGE TYPE ON STEER UTILIZATION FROM ONE ACRE OF FEED

Forage type	Dry matter available	Dry matter consumed	Amount consumed	Gain per 100 pounds of forage
	pounds	*pounds*	*per cent*	*pounds*
1954:				
Alfalfa soilage	7,659	6,893	90	9.3
Alfalfa pasture	7,198	3,743	52	11.9
1956:				
Alfalfa soilage	2,688	2,460	92	5.8
Alfalfa pasture	2,711	1,612	59	8.6
1956:				
Trefoil-orchardgrass soilage	1,562	1,517	97	8.4
Trefoil-orchardgrass pasture	1,567	1,389	82	7.7

TABLE 18

ALFALFA VS. PASTURE MIX—STEERS VS. LAMBS*

Item	*Alfalfa* Soilage	*Trefoil-orchard-grass* Soilage
Beef steers		
Average daily gain, pounds	1.50	1.76
Feed per pound gain, pounds	17.1	12.1
TDN content of forage DM consumed	56.5	66.0
Average terminal grade	Standard	High-standard
Beef produced per acre, pounds	563	444
Feeder Lambs		
Average daily gain, pounds	0.21	0.24
Feed per pound gain, pounds	15.0	10.6
TDN content of forage DM consumed	58.0	64.5
Average terminal grade	High-good	High-good
Lamb produced per acre, pounds	463	417

* Length of trial - 108 days.

SOILAGE FOR CATTLE

Even if cattle select a more highly nutritious forage from pasture, soilage results in greater production because more of the available dry matter is consumed (table 17). Only 52 to 59 per cent of the available forage on alfalfa pasture was consumed compared to 90 to 92 per cent from soilage. Trefoil-orchardgrass was a more nutritious forage (table 17), and a greater proportion (82 per cent) was consumed by pasturing.

Haying, although producing more beef than pasturing, produced only 79 to 85 per cent as much as soiling (table 19). Haying and soiling produced lower gains than grazing, even though the steers consumed more feed. Efficiency of forage utilization was also lowest for steers fed alfalfa as hay. It must be kept in mind, however, that greater quantities of beef were produced from soiling followed by haying.

TABLE 19

BEEF PRODUCTION PER ACRE FROM DIFFERENT METHODS OF UTILIZATION

Year	Rotation grazing				Soilage		Haying
	10 day	6 day	1 day	Strip	Fresh	Wilted	
	per cent of production from soilage						
1952	59	..	82	..	100	81	..
1953	..	77	79	..	100	..	85
1954	..	64	..	68	100	..	79
1956	..	80	..	..	100	..	..

Even wilting the alfalfa to 40 per cent moisture before feeding produced less beef than soiling (table 19). Grazing and soiling produced comparable gains but the animals fed soilage consumed more feed and produced less gain per unit of feed (table 17). The higher feeding value of soilage compared to hay is further illustrated by the greater quantities of concentrates needed to fatten steers when hay was fed (table 20). In this trial lower gains resulted from hay feeding than from soilage feeding, but when soilage and hay were supplemented with concentrates gains were almost equal because greater concentrate consumption resulted thus overcoming the lower quality of the alfalfa hay.

TABLE 20

STEER RESPONSE TO CONCENTRATE SUPPLEMENTATION (1957)

Feed	Daily gain	Feed intake: Roughage	Feed intake: Concentrate
	pounds	*pounds*	*pounds*
		Unsupplemented	
Soilage	1.96	17.7	...
Hay	1.60	18.2	...
		Supplemented	
Soilage	2.21	21.5	5.5
Hay	2.16	11.5	7.7

TABLE 21

BEEF PRODUCTION PER ACRE FROM ALFALFA

Year	Days	Soiling: Fresh	Soiling: Wilted	Haying
		pounds beef per acre		
1952	168	704	568	...
1953	155	678	...	576
1954	132	1,080	...	856
1956	108	563	...	...

It appears that pasturing allows steers to consume a higher-quality forage. Soilage has a lower quality than pasture because animals are forced to consume more of the coarser parts of the plant. Hay, however, is still of lower quality than soilage because leaf and fine stem losses occurred in hay making. Soilage prevented not only the animal-induced forage loss in pasturing but also the machine-induced forage loss because it is a drier product to handle. In general, the average increase found from soilage in California trials has been about 30 per cent. It was concluded that soilage will give the greatest production per acre from the same forage. This, however, doesn't mean that it is always the most economical method for forage utilization. Unless there are other considerations, soiling is the most productive method of processing forage for greatest beef production per acre.

Even though TDN, for the most part, will measure differences in forage quality, it is not the ultimate in the measurement. This is noted when gain produced per 100 pounds of TDN is computed. The TDN consumed by the steers on pasture was utilized more efficiently than that consumed from soilage or hay. Soilage exceeded hay. The TDN of the pasture, therefore, has a higher net energy than the TDN of soilage or hay. This conclusion emphasizes the need for the measurement of forage value to be on some basis which involves the net-energy principle.

Table 21 gives some beef production figures for soilage. Note that more than 1,000 pounds of beef per acre can be obtained from this method of forage utilization.

SUPPLEMENTATION

Supplementation of grazing cattle has been practiced for many years. Although relatively good gains can be achieved when the sole source of feed is high-quality pasture forage, it is well recognized that an additional source of energy is needed to produce a finished animal with a high dressing percentage and a high grading carcass in a reasonable feeding period.

Table 22

SLAUGHTERING DATA OF STEERS SUPPLEMENTED FOR VARYING PORTIONS OF THE TOTAL FEEDING PERIOD

Supplemental treatment	Dressing percentage	Carcass grades		
		Choice	Good	Standard or commercial
		per cent		
None	56.7*	8	75	17
Supplemented 2nd 84 days	58.9*	18	82	0
Supplemented for 168 days	60.8*	64	36	0

* All statistically significantly different (P = 0.05).

SUPPLEMENTATION OF ALFALFA

Although relatively high gains can be achieved when high-quality alfalfa in the form of soilage or hay is the sole source of feed, an additional source of energy is needed to produce an acceptable slaughter animal (table 22). It was shown in an earlier study (Meyer *et al.*, 1953) that barley, fed at the rate of 1 pound per 100 pounds of body weight to steers receiving pasture, brought about an increased daily gain of approximately 0.5 pound. Table 23 gives similar results for steers grazing trefoil-orchardgrass pasture. Molasses alone was shown to be unsatisfactory as a supplement to alfalfa soilage. Other observations have revealed that a mixture of barley and molasses-dried beet pulp (hereafter referred to merely as beet pulp) is a satisfactory supplement to both alfalfa soilage and hay.

Table 23

EFFECTS OF LIMITED SUPPLEMENTATION FOR STEERS GRAZING TREFOIL-ORCHARDGRASS PASTURE

Item	Amount of supplement fed	
	0	5 pounds per head per day
Days on feed	142	142
Number of animals	21	21
Initial weight, pounds	634	631
Average daily gain, pounds	1.50	1.75
Dressing percentage	57.9	60.8
Carcass grade: per cent of animals in grade		
Good	5	67
Standard	86	33
Utility	9	0

Steers fed alfalfa alone have consistently made good body weight gains, especially during the first half of a 130- to 179-day feeding period, in contrast to steers receiving supplements continuously for the entire period. It seemed important to determine whether a concentrate supplement fed only during the last half of the feeding period produced gains comparable to those produced by supplementing continuously for the entire period. It also seemed important to determine at what level the supplement should be fed.

SUPPLEMENTATION OF ALFALFA SOILAGE AND HAY

Yearling Hereford steers weighing approximately 665 pounds were randomly assigned to six groups for an experiment. The hay fed had been harvested at approximately 10 per cent bloom at the Imperial Valley Field Station the summer preceding the study; soilage had also been harvested at 10 per cent bloom. Hay or soilage was allowed *ad libitum*. Barley and beet pulp were fed in a ratio of 3:1, and supplemented lots were allowed all the supplement they would eat twice daily. All lots were allowed a small amount of oat hay (approximately 1.8 pound daily) to assist in preventing bloat.

Statistical analysis revealed no significant difference in response to the supplements between the animals fed soilage and those fed hay. The daily gains and the

roughage consumption of hay or soilage were not significantly different. The supplemented steers on hay, however, consumed an average of 2.2 pounds per head per day more concentrate than those on soilage. Since the gains were not different, the hay, therefore, was of lower nutritive value than soilage. Because the response to supplement is similar, the data from the lots fed hay have been combined with those from the lots fed soilage and are presented in table 24.

Concentrate supplementation during the second half of the feeding period resulted in a highly significant increase in daily TDN consumption of 3.2 pounds per day, although there was a significant drop in roughage consumption. The daily gain in the same period was increased by 0.72 pound. Daily gain of the unsupplemented lot dropped 0.22 pound during the second half of the feeding period. However, providing 7.6 pounds of concentrate daily prevented this loss and increased the daily gain 0.37 pound above the gain of the first half. Supplementation throughout the 168-day period resulted in a further decrease in roughage consumption with only a slight increase in TDN intake. The daily gain was not increased over the group receiving supplement only during the last half of the period, although approximately 75 per cent more supplement was used over the 168 days.

It appears from these data that supplementation throughout the feeding period is wasteful of concentrate, because the extra supplement reduced roughage intake but did not increase weight gain. Inspection of the slaughter data shows that those steers supplemented throughout the 168 days, although gaining no more, yielded a significantly higher percentage of dressed carcass and graded considerably higher (table 22). A higher energy ration, therefore, may produce fatter carcasses without increasing the rate of gain.

Further calculations estimate the daily energy gain of 2,644, 4,049 and 5,722 kilocalories for the unsupplemented lots, for those supplemented the last 84 days, and for those continuously supplemented, respectively. The lot receiving continuous supplementation thus gained 40 per cent

TABLE 24

RESPONSE OF STEERS SUPPLEMENTED FOR VARYING PORTIONS OF THE TOTAL FEEDING TIME

Supplemental treatment	Steers	Portion of feeding period	Initial weight	Daily gain	Daily air-dry feed intake		Daily TDN intake
					Roughage	Concentrate	
	Number	*days*	*pounds*				
None	12	1st 84 days......	670	1.89	16.7	0	8.9
		2nd 84 days.....	829	1.67	19.2	0	10.2
		Entire period (average)	670	1.78	18.0	0	9.6
Supplemented 2nd 84 days	11	1st 84 days......	666	2.02	16.2	0	8.6
		2nd 84 days.....	836	2.39	14.1	7.6	13.4
		Entire period (average)	670	2.21*	15.2*	3.8	11.0*
Supplemented for 168 days	11	1st 84 days......	660	2.50	12.2	5.7	10.9
		2nd 84 days.....	870	1.86	11.8	7.5	12.1
		Entire period (average)	660	2.18*	12.0*	6.6*	11.5*

* Difference statistically highly significant, as compared to the unsupplemented lot.

more energy than the lot supplemented only the last 84 days, although the gain in body weight was the same for the two lots.

A consideration of all data prompts the conclusion that, in order to produce a high-grading and high-yielding carcass, continuous supplementation was more satisfactory than no supplementation or supplementation only during the last half of the feeding period.

AMOUNT OF SUPPLEMENT TO FEED WITH ALFALFA

High-quality Hereford steers were randomly divided into six lots of eight head each. Five of the lots were allowed alfalfa soilage *ad libitum* with various levels of barley and beet pulp supplement. One lot received no supplement, while a second received all the supplement they would eat twice daily. The remaining three lots being fed soilage received the supplement at the rate of 25, 50, and 75 per cent of the amount consumed by the full-fed lot. The sixth lot was allowed alfalfa hay *ad libitum* plus the supplement full fed. The alfalfa soilage and hay were again harvested from the Imperial Valley Field Station at approximately 10 per cent bloom.

Feeding a supplement (table 25) above 3.5 pounds per head per day (50 per cent of full feed) to animals on alfalfa soilage produced no significant increase in weight gain. Increasing the supplement to 5.1 and 6.2 pounds per day (75 to 100 per cent of full feed) brought about an increased TDN consumption but no increased weight gain. It is again interesting to note that the steers full-fed supplement on alfalfa hay ate more concentrate than those full-fed supplement on alfalfa soilage. The difference in gain was not statistically significant.

As in the case of the previous experiment, if only body weight gain and TDN consumption are considered, erroneous conclusions may be made. From these data alone it appears that there is no advantage to feeding more than 50 per cent of full feed or 3.5 pounds per head per day (approximately 0.5 pound per 100 pounds body weight). Again, however, if yield and grade data are considered, the conclusion is altered. Although increasing the supplement above 3.5 pounds did not significantly stimulate daily gains, it brought about a significant increase in the dressing percentage and carcass grade (table 25).

It was concluded that gains made by steers continuously supplemented with

TABLE 25

RESPONSE OF STEERS TO SUPPLEMENTS FED AT DIFFERENT LEVELS WITH ALFALFA SOILAGE AND FULL FED WITH HAY

Measurements	Alfalfa soilage					Alfalfa hay
	Supplement fed at following percentage of full feed					Supplement full fed
	0	25	50	75	100	
Initial weight, pounds	541.0	545.0	543.0	542.0	543.0	539.0
Daily gain, pounds	2.01	2.17	2.28	2.34	2.35	2.53
Daily air-dry feed consumed, pounds						
Roughage	18.3	17.1	14.6	14.0	12.5	11.7
Concentrate	0.0	1.8	3.5	5.1	6.2	8.5
Total	18.3	18.9	18.1	19.1	18.7	20.2
TDN intake, pounds per day	10.1	10.7	10.7	11.6	11.6	12.7
Dressing, per cent	58.5	57.7	58.3	59.7	59.8	60.4
Carcass grade, number in grade						
Choice	0	0	1	4	3	4
Good	7	8	7	4	5	4
Standard or commercial	1	0	0	0	0	0

Table 26

COMPARISON OF EFFECTS OF FULL FEEDING STEERS

	1960–rolled barley			1961–ground barley		
	Pasture		Drylot	Pasture		Drylot
Amount of concentrate fed, per cent of ration*	0	100¶	70	0	100¶	70
Days on feed	119	134	134	126	118	133
Number of animals	8	12	8	8	12	8
Daily intake of concentrate, pound	0	12.3	12.5	0	13.5	11.8
Initial weight, pound	555	560	596	624	675	652
Average daily gain, pound	1.49	2.63	2.59	0.93	2.33	1.93
Dressing percentage	56.3	60.0	62.5	54.0	61.2	60.5
Average per cent fat in carcass†	15.1	19.8	22.2	11.9	23.3	20.1
Average carcass score‡	3.0	5.7	6.0	4.2	7.3	7.1
Average carcass weight, pound	386	556	584	423	594	565
Averagec orrected carcass weight, pound§	332	555	684	326	651	567

* The pasture plus barley and drylot steers were implanted with 30 mg of diethylstilbestrol at the start of the trial.
† Average per cent fat in a choice carcass = 23.6.
‡ 9 = average choice, 6 = average good, 3 = average standard.
§ Corrected to a carcass weight equivalent to a carcass containing 1.297 kcal per pound, 17.3 per cent protein and 20 per cent fat.
¶ Includes barley only.

concentrate represented more energy than gains of steers not supplemented or supplemented for only the last half of the experiments. This occurred even though weight gains were the same. Variations in the quantity of concentrate supplementation produced a similar result. Weight gains did not increase above a certain amount of supplementation but energy gains did increase resulting in higher yield and better carcass grades. It was also concluded that supplementation of pure alfalfa with high energy concentrates is necessary to produce optimum fattening of beef steers resulting in choice carcasses.

LIMITED SUPPLEMENTATION OF IRRIGATED PASTURE

The limited feeding of ground barley to steers grazing irrigated pasture was studied. The intake of the barley was controlled by mixing salt with the barley. The results obtained (table 23) showed that an increased daily gain could be obtained along with improvement in dressing percentage and carcass grade. The additional intake of barley above pasture did not, however, produce a "choice" animal at the end of the feeding period.

"FULL FEEDING" ON PASTURE

For the production of acceptable carcasses from cattle grazing irrigated pastures a simplified approach in feeding of the grain supplement was tried. In addition to the pasture, barley was fed free choice. This comparison was made each year to a group receiving only irrigated forage and to one receiving in the feedlot a 70 per cent concentrate ration. The stocking rate, over normal carrying capacity with no supplement, was doubled to 5.4 head per acre. Table 26 gives the results obtained during two different years using both ground and rolled barley.

It is difficult to compare years, but it was concluded that either physical form of the barley proved satisfactory for fattening the cattle. Another aspect of these trials was that the animals receiving barley free choice in addition to the pasture, upon slaughter, showed no signs of "yellow" fat in the carcasses.

An additional trial was conducted using these same pastures with a comparison of rolled milo vs. rolled barley for pasture fattening of cattle.

No differences were found between the different treatments (table 27). The pasture

Table 27

PASTURE VS. DRYLOT FATTENING OF STEERS

Ration	Rolled barley plus pasture	Rolled milo plus pasture	70 per cent concentrate drylot ration
Number of days on feed	150	150	144
Number of animals	6	6	7
Daily intake of concentrates, pounds	13.7	13.4	12.2*
Initial weight, pounds	631	628	601
Average daily gain, pounds	2.34	2.37	2.44
Dressing percentage	60.9	61.1	62.1
Average per cent carcass fat	23.1	22.9	21.8
Average carcass grade†	7.0	7.1	7.2
Average 20 per cent fat corrected carcass, pounds‡	652	652	622

* Animals consumed 17.4 pounds per day total ration.
† USDA grade, 7 = high good.
‡ Corrects carcass weight to 1,297 kcal per pound, 20 per cent fat and 17.3 per cent protein.

steers consumed slightly more grain than the drylot steers but had a slightly lower dressing percentage. The pastured animals had slightly higher fat content in their carcasses so when the carcass weights were corrected to a 20 per cent fat basis to give a more correct comparison between treatments, these differences are no longer evident. There was no difference in final carcass grade. At slaughter no sign of "yellow" fat in the carcasses was noted. It was concluded that either rolled or ground barley or rolled milo was acceptable when full-fed with pasture.

From the results obtained the following recommendations are set forth: (1) a high-producing but palatable pasture containing a mixture of legumes and grasses is needed; (2) the usual stocking rate of the pasture can be doubled; (3) the desired grain can be fed free-choice and kept constantly available after a three-week period in which the animals are brought on feed; (4) cattle should be rotated among fields within the pasture to keep the forage palatable and to facilitate irrigation; (5) control of internal parasites is necessary; (6) since this is a high-energy ration an increased daily gain can be expected with a 30-milligram implant of diethystilbestrol.

Use of this system should result in the cattle consuming from 10 to 15 pounds of grain plus enough pasture to gain between 2.25 and 2.75 pounds daily and reaching acceptable slaughter condition in 120 to 150 days. Because of the limited length of most pasturing seasons the starting weight of the cattle should be 700–750 pounds in order to finish at 1,000–1,050 pounds live weight.

ENERGY REQUIREMENTS FOR GRAZING

Various estimates have been made for the energy needs of grazing animals in relation to drylot feeding. Reid *et al.* (1958) estimated that as much as 3.4 pounds of TDN is needed for grazing animals above the amount needed for animals confined to a barn. Greenall (1959) found that grazing wether lambs had a greater energy requirement than suggested by standard values.

It is difficult to obtain information on energy requirements of grazing animals. As it is possible to measure feed intake of grazing animals and also the energy content of the weight gain an experiment to measure requirements of grazing and non-grazing steers was conducted.

Body composition and forage intake were available from a previous experiment where five lots of steers grazed irrigated pasture at various stocking rates (table 28) (1.35, 2.25, 3.06, 3.93 and 4.68 steers per acre), making rates of gain from 0.80 to

Table 28

INFLUENCE OF STOCKING RATE ON STEER PERFORMANCE AND INTAKE

Item	Pasture					Soilage Lot 6
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	
Number steers per lot	3	5	7	9	11	8
Steers per acre	1.35	2.25	3.06	3.93	4.68	3.24
Average daily gain, pounds	1.81	1.72	1.44	1.31	0.80	1.49
Average daily intake, pounds DM	16.9	14.5	13.8	12.7	13.2	18.0

1.81 pound per day. One lot of steers was fed soilage from the same pasture and served as a nongrazing control fed in drylot, having a reduced activity because of confinement to a small lot (50x50 feet).

A behavior study was included to determine activity of the various lots. Four 24-hour observation studies were made during a typical grazing period of one week on days 1, 3, 5 and 7 that the animals were in the field. Observations were made every 15 minutes during the 24-hour day on the number grazing, standing and lying.

ENERGY REQUIREMENTS COMPARED

As the stocking rate increased, food and energy intake, weight gain and energy retention decreased (figure 7).

It was shown in the production data (table 28), and with the measurement methods used in this experiment, that the maintenance requirement for grazing steers was not greatly different from nongrazing steers. When digestible energy intake per unit of $W^{3/4}$ pounds was plotted against energy gain for the steers in this experiment and compared to those fed in a drylot (1959) no differences in the slopes of the lines were observed, giving evidence of no differences in digestible energy needs per unit of energy gain (figure 12). The elevations of the lines were not statistically different either and therefore do not give evidence of a difference in the maintenance requirement between the grazed steers and steers fed in drylot.

It is suggested by these data that the extra activity involved in grazing on irrigated pasture does not result in a measurable increase in digestible energy requirements.

BEHAVIOR

It was shown in the behavior study that three times as much time was spent eating (grazing)—12.2 versus 4.2 hours—by the steers on pasture than those on soilage. It might be assumed from this that greater activity was required for grazing than eating soilage. Significantly more time was spent idling, either standing or lying, by steers fed soilage than by those grazing. As the stocking rate was progressively increased from lot 1 through lot 3 significantly more time was spent grazing and less time standing or lying, undoubtedly because of the greater competition for forage as grazing intensity increased. This was only true up to a point under a rotational grazing system, and the steers reached a point where they did not increase grazing time although the forage available was quite limited. The study also revealed that this greatei activity did not result in increased measurable energy requirements for grazing.

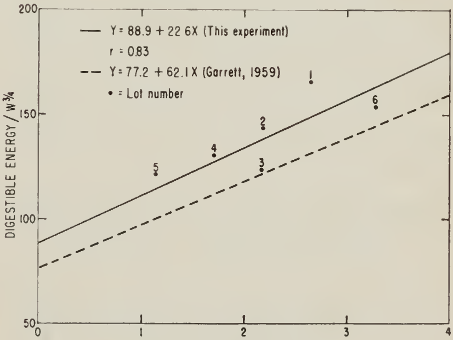


Fig. 12. Regressions of digestible energy intake on energy gain for grazing steers.

COMPENSATORY GROWTH

It has generally been accepted that continuous growth is the most economical system for growing and fattening steers (Wilson and Osbourn, 1960). Research work has shown that when cattle are restricted in growth during the winter they will gain weight more rapidly than control animals after being turned onto summer range (Bohman, 1955). (*An animal whose growth has been retarded exhibits, when restriction is removed, a rate of growth greater than that which is normal in animals of the same chronological age. This abnormally rapid growth relative to age is termed "compensatory growth."*) The ability of the animals to compensate for low winter gains appears to be influenced by several factors: the age of the animal, the severity of winter growth retardation, and the quantity of feed available during the summer. Also in these trials, weanling cattle at the end of the summer grazing season were not able to catch up in total body weight to control animals, while yearling cattle were able to compensate for low winter gains. Optimum wintering feeding rates for calves typical of animals raised in southern Oregon has also been investigated.

It has also been shown that irrigated pasture is a good growing ration, but that it is not sufficient to produce a finished animal. The use, however, of irrigated pasture or in general grazed forage to help diversify and balance feed production has long been practiced. Therefore, the role of irrigated pasture in a growing and subsequent fattening regime of beef cattle was explored. The plane of nutrition during winter is not ignored, and its effects on the utilization of pasture and subsequent performance is also reported.

WINTERING AND PASTURING FOR COMPENSATORY GROWTH

Weanling steers were allotted at random to a fattening ration or a growing ration. The growing ration was either long or pelleted hay and was fed in group pens (full-fed on pellets and limited-fed on long hay). Following the growing period some were fattened; others grazed irrigated pastures consisting of a mixture of orchardgrass and ladino clover. From results of previous trials, a 7-day grazing period followed by a 35-day recovery interval between grazings was practiced. Energy intakes were varied by varying stocking rates on the irrigated pasture. Fattening was done by feeding a 70 per cent concentrate ration to individually fed steers. At the end of each feeding treatment, representative animals were slaughtered to determine body composition and carcass characteristics. All animals were weighed every 28 days after an overnight stand without feed or water.

During the growing phase of 172 days, the steers fed the pelleted hay consumed 15.8 pounds of dry matter and gained 1.76 pounds per day, exceeding the daily feed intake of 10.2 pounds and daily gain of 0.77 pound per day made by the steers fed on long hay. This resulted in the animals going into the pasture phase different in body composition because of the wintering treatment.

The three different stocking rates used resulted in three separate energy intakes on irrigated pasture (table 29). Forage data obtained on this trial showed differential seasonal production of forage dry matter. The heavier stocking rate decreased the forage available by the end of the grazing season. The heavier stocking rates also favored legumes while the lighter stocking rates tended to favor grasses.

Forage production of each pasture was equal each season at the start of these trials, regardless of the previous year's treatment—no significant differences were found in the initial sampling at that time. The chemical analysis of the forage available showed a decrease in lignin and an increase in crude protein as the stocking rate increased. This indicates that the animals were offered a more nutritious forage when the pastures were more heavily grazed, mainly because the forage was less mature due to a slower recovery rate. In contrast, the dry-matter digestibility was lowered as grazing intensity increased. A heavy stocking rate forced the animals to consume more of the coarser portions of

Table 29

STEER RESPONSE TO PASTURE TREATMENTS FOLLOWING TWO WINTER FEEDING SYSTEMS

	Growing phase — energy intake					
	Medium*			Low†		
	Pasture phase — energy intake					
	Liberal	Medium	Low	Liberal	Medium	Low
Day on pasture	124	124	124	124	124	124
Number of animals	12	12	18	12	12	18
Animals carried/acre	1.8	3.6	5.4	1.8	3.6	5.4
Daily feed, pounds (dry basis)§	18.1[a]	15.3[b]	11.6[c]	18.0[a]	14.5[b]	12.6[c]
Average daily gain, pounds§	1.15[b]	0.84[c]	0.41[d]	1.67[a]	1.26[b]	0.85[c]
Final weight, pounds	832	803	749	737	683	659
Feed consumed/pounds gain	15.7	18.2	28.3	11.0	11.5	14.8
Carcass data						
Dressing percentage	58.2	55.2	55.0	53.8	53.8	54.2
Fat percentage§	16.5[c]	12.9[a]	11.2[ab]	12.1[a]	10.3[ab]	9.0[b]
Marbling score‡	2.5	2.0	1.6	1.5	1.2	1.1
Backfat, inches§	0.42[c]	0.29[a]	0.27[a]	0.27[a]	0.26[a]	0.14[b]

* Previous daily gain — 1.76 pounds; feed intake — 15.8 pounds; carcass fat — 14.3 per cent; marbling score — 2.6; backfat — 1.0 inch; in 172 days.
† Previous daily gain — 0.77 pound; feed intake — 10.2 pounds; carcass fat — 7.2 per cent; marbling score — 1.0; backfat — 0.26 inches; in 172 days.
‡ USDA grade — 1 devoid, 2 practically devoid, and 3 trace.
§ a, b, c, d. Means on the same line having the same superscript do not differ significantly.

the forage, even though the entire plant was initially lower in lignin.

Compensatory growth of the cattle occurred since all steers previously fed the low-energy intakes during the growing phase made greater rates of daily gain on pasture than those previously fed the medium-energy intakes (table 29). This compensatory growth resulted in approximately 0.4 pound increase in daily gain when steers had previously been fed a low-energy diet. The different grazing intensities were for 124 days for all lots, and even with compensatory growth, carcass differences were obtained. The carcass traits improved at all levels of grazing intensity for those previously given the low-energy intakes during winter when compared to those from the medium-energy wintering ration. Fat content, marbling score, and backfat thickness improved during the grazing period, even for those steers on a medium- and low-energy intake from grazing. Consumption of forage per animal decreased as the stocking rate increased, resulting in decreased production per animal. The production-per-unit area (figure 13), a more realistic evaluation of grazing, shows that consumption per acre increased even though it decreased per animal. Live weight gain per acre increased to the medium-grazing intensity and then leveled off for those animals given the low-energy intakes during winter while it increased to the medium-energy intake and then declined for those receiving the medium-energy wintering treatment. Carcass gain per acre increased for those from a low-energy wintering ration, and declined for those previously fed a medium-energy ration. Considering all of the data it appears that some latitude is available in a choice of stocking rates for animals previously fed a low-energy wintering ration. This is not true for the steers previously fed a medium-energy intake, as carcass gain per acre decreased with each subsequent increase in stocking rate. It, therefore, appears that best utilization of irrigated pasture by growing beef steers results from animals which have previously been on a low plane of nutrition.

COMPENSORARY GROWTH IN THE FEEDLOT

Rapid rates of gain were attained during the fattening period following pasture

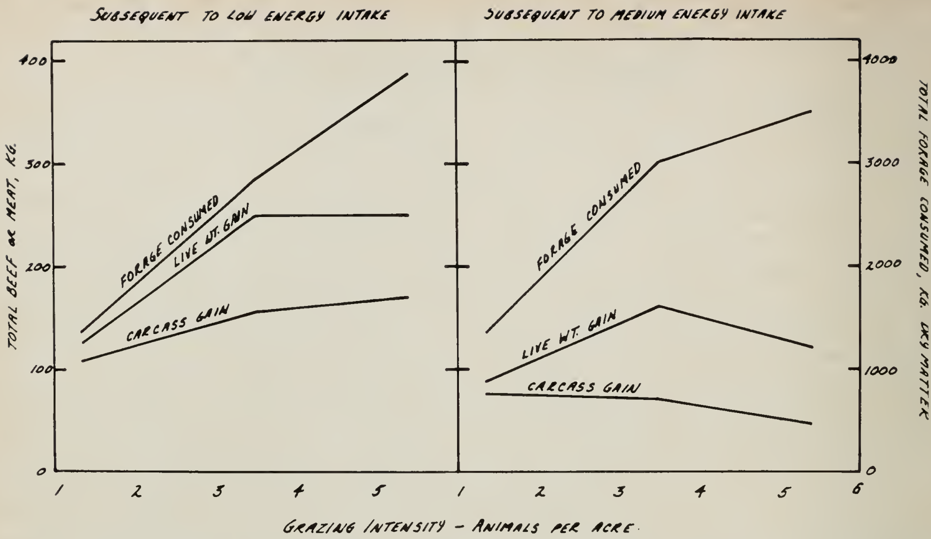


Fig. 13. Influence of grazing intensity on production or consumption per acre as determined by grazing steers.

(table 30). Those making the least gains on pasture made the greatest gain in the feedlot. Efficiency of feed utilization was generally greater for those making the most rapid gain. Feed efficiency has to be interpreted with caution because of variations in rumen fill.

Body characteristics (table 30) at the end of the fattening period were essentially equal for all treatments, except that differences were apparent for the steers allotted to the pasture treatments. These characteristics varied as expected, according to previous grazing intensity. The marbling score and carcass fat percentage were about the same for these steers as for the steers fattened in the feedlot without previous periods of hay or pasture feeding.

Since approximately the same carcass weights and body fat percentages were attained, feed requirements for all treatments can be directly compared as they resulted in comparable total energy gains (table 31). Steers fattened immediately in the feedlot required less roughage, but more concentrate than those grown first on either a low-energy or medium-energy ration and then fattened. The animals making the low rate of gain during growth required less roughage but more concentrate than animals making a rapid rate of gain on a medium intake during the growing period. In the former case, 58 per cent of the total feed consumed was roughage, while in the latter 69 per cent of the total feed consumed was roughage.

Steers that are pastured before fattening require greater quantities of roughage and lesser amounts of concentrate to reach market condition. The heavier grazing intensities increased the requirement of concentrate and decreased the roughage requirement. The necessary proportion of roughage in the steer's total food requirement, when grown slowly, pastured and then fattened, varied between 72 and 78 per cent. If the steers previously had been grown rapidly and subsequently pastured previous to fattening, the roughage proportion in his ration would vary from 82–87 per cent.

If weanling steers were fed the roughage ration so as not to make maximum gains, growth rate in the subsequent fattening period was relatively greater (compensatory growth) than that for animals directly fattened. Steers grazing irrigated pasture previous to fattening required a longer time to reach market condition. If the grazing intensity was sufficiently severe to decrease rate of gain, compensatory growth took place in the feedlot following pasturing.

Table 30

STEER RESPONSE TO HIGH ENERGY RATION FOLLOWING VARIOUS GROWING METHODS*†

		Growing phase — energy intake							
		Medium				Low			
		Pasture phase — energy intake							
		High	Liberal	Medium	Low	High	Liberal	Medium	Low
				Fattening phase — energy intake					
Item	High*	High	High	High	High	High	High	High	High
Days on high energy	222	124	62	71	71	149	92	101	102
Number of animals	20	12	6	6	9	12	6	6	9
Daily feed, pounds (dry basis)	15.9	17.4	18.8	19.9	19.7	17.5	19.8	20.3	21.0
Average daily gain, pounds‖	2.32^{ad}	2.15^{a}	3.40^{b}	3.35^{b}	3.78^{c}	2.48^{d}	3.30^{b}	3.29^{b}	3.61^{c}
Final weight, pounds	960	967	1,036	1,038	1,010	909	1,000	1,002	1,009
Feed consumed/pounds gain, pounds	6.8	8.1	5.5	5.9	5.2	7.0	6.0	6.2	5.8
Carcass data									
Dressing percentage	61.4	62.2	59.6	59.5	58.7	61.6	59.1	59.1	59.3
Fat percentage‖	24.1^{a}	21.3^{ab}	20.9^{b}	20.0^{b}	20.0^{b}	23.1^{a}	21.7^{ab}	22.2^{ab}	20.4^{b}
Marbling score‡	5.5	4.6	4.7	4.8	4.6	4.9	4.8	4.0	4.4
Backfat, inches	0.79	0.65	0.52	0.55	0.59	0.70	0.63	0.72	0.59
Final grade§	7.9	6.6	6.8	6.8	6.3	6.7	7.5	6.3	7.0

* High energy fattening ration — 20 per cent alfalfa hay, 10 per cent oat hay, 65 per cent rolled barley, 3.5 per cent cottonseed meal, 1 per cent fat, 0.5 per cent oyster shell, 0.5 per cent salt.

† 24 mg stilbestrol implanted at start of high energy fattening ration feeding period.

‡ USDA grade — 4 slight, 5 small, 6 modest.

§ USDA grade — 6 average good, 7 high good, 8 low choice.

‖ a, b, c, d, means on the same line having the same superscript do not differ significantly.

Table 31

STEER RESPONSE—VARIOUS FEEDING METHODS, SUMMATION

Item			Growing phase — energy intake						
			Medium			Low			
			Pasture phase — energy intake						
		High	Liberal	Medium	Low	High	Liberal	Medium	Low
			Fattening phase — energy intake						
	High	High	High	High	High	High	High	High	High
Days	222	296	358	367	367	321	388	397	398
Concentrates, pounds	2,471	1,511	817	987	980	1,826	1,276	1,434	1,501
Roughages, pounds	1,059	3,365	5,307	5,039	4,580	2,536	4,539	4,169	3,959
Roughage, per cent	30	69	87	84	82	58	78	74	72
Net energy required, megcals	1,964	2,228	2,598	2,588	2,518	2,179	2,562	2,555	2,501
Energy for growth and fattening, per cent	46	37	35	33	33	39	35	34	32

In these trials the main difference between the various systems of growing and fattening was in the length of time required for steers to reach market condition and the proportion of the total energy required which was used for growth and fattening above maintenance (table 31). It would, therefore, seem that the system to use must be based on relative cost of roughage and concentrates, market conditions, and the length of feeding period desired.

REASONS FOR COMPENSATORY GROWTH

From these trials information is available to explain in part the reasons for compensatory growth and its influence on the efficiency of feed utilization during refeeding. The data suggest two explanations: (1) an increase in feed capacity (the daily feed intake per unit of metabolic body weight); and (2) an increase in the efficiency of energy utilization independent of feed intake.

ROLE OF IRRIGATED PASTURE

IRRIGATED PASTURE AS AN ENERGY SOURCE

High producing irrigated pasture as the entire ration is both an energy and a protein source. The relative value of irrigated pasture in California compared to barley and alfalfa hay as energy sources and alfalfa hay and cotton seed meal as protein sources is shown in table 32. In this case irrigated pasture as an energy source was 60 per cent less expensive than barley and alfalfa hay during the last 10 years in California, while it was 51 per cent less expensive than cottonseed meal as a protein source. Yet, the number of cattle in feedlots fed harvested grains and forages increased in the past 10 years while fewer are carried on irrigated pasture.

An experiment was conducted whereby irrigated pasture was compared primarily as a sole energy source, as an energy source in conjunction with feedlot fattening, and a supplemental feed (source of protein, minerals, vitamins and fiber) to barley grain as the primary energy source. All are then compared to feedlot fattening on harvested feeds.

The cost study on these data merely ap-

Table 32

RELATIVE VALUE OF IRRIGATED PASTURE IN CALIFORNIA

	Energy source			Protein source		
	Pasture*	Barley†	Alfalfa hay†	Pasture	Alfalfa hay†	Cottonseed meal†
	acre	ton	ton	acre	ton	ton
Value, dollars‡	76.40	56.33	32.80	76.40	32.80	70.60
Value per megcal. net energy, cents	1.6	3.9	4.0	...	...	...
Value per pound crude protein, cents	...	...	...	4.1	10.7	8.5

* Irrigated pasture stocked at 3.9 steers per acre. (Hull *et al.*, 1961). Cost data calculated from Peterson *et.al.*, 1959 and considered to be representative of the 1951–61 pasture cost.
† Ten-year average prices 1951–61 in San Francisco. Federal-State Market News Service, 1961.
‡ Recent average cost figures are not available but the relative relationships have not changed even if prices have.

plied the 10-year average prices of harvested feeds for 1951–61 (Federal-State Market News Service, 1961) and pasture costs for 1951–61 (Peterson *et al.*, 1959). Pasture cost was only feed cost, and does not include animal management or nonfeed expense.

Response of animals (table 33) indicates that pasture of good quality did not produce live weight gains equivalent to those fed on a feedlot ration high in concentrate unless carbohydrate concentrate was fed with the pasture. Energy gains, moreover, showed greater differences than indicated by weight gains. Carcass fat content was approximately 21 per cent when maximum quantities of concentrate were fed while the fat content of those given pasture only was 11 per cent. Grade and marbling score gave confirmatory results.

The animals fed in the feedlot following pasturing made a greater daily weight and energy gain than did those fattened immediately whether on pasture or in the

Table 33

PRODUCTION FROM PASTURE UTILIZED AS AN ENERGY AND SUPPLEMENTAL FEED SOURCE BY STEERS

	Pasture followed by feedlot		Pasture fattening	Feedlot†
	Pasture*	Feedlot*†		
Number of animals	16	8	24	16
Number of days	122	88	112	122
Daily gain, pounds	1.08	3.19	2.48	2.26
Final weight, pounds	731	1,006	896	898
Daily feed, pounds	14.4	19.4	12.7‡	16.9
Daily energy gain, megcals	0.70	6.83	5.18	4.69
Carcass data§:				
Weight, pounds	399	599	554	553
Fill, pounds¶	83	68	23	27
Fat, per cent‖	11.0	21.6	21.1	21.2
Grade score**	3.5	5.9	6.2	6.6
Marbling score††	1	4.1	3.2	4.5

* After 122 days on pasture, eight steers were slaughtered for carcass data and eight were fattened in the feedlot for 88 days.
† Fattening ration contained 20 per cent alfalfa hay, 10 per cent oat hay, 63.5 per cent barley, 3.5 per cent cottonseed meal, 2.0 per cent molasses, 0.5 per cent oyster shell, and 0.5 per cent salt.
‡ Barley only.
§ Representative steers sacrificed before the trial began contained 11.3 per cent fat in the carcass, 52 pounds of fill, and the carcass weighed 341 pounds.
¶ Estimated by the method of Lofgreen *et al.* (1962).
‖ Initially the carcasses contained 11.3 per cent fat.
** USDA grade — 3 average standard, 6 average good, 9 average choice.
†† USDA grade — 1 devoid, 3 trace, 4 slight, 5 small.

TABLE 34

COST STUDY ON PASTURE UTILIZED AS AN ENERGY SUPPLEMENTAL FEED SOURCE FOR STEERS

	Pasture followed by feedlot			Pasture fattening†	Feedlot
	Pasture*	Feedlot	Total		
Pasture cost per animal, dollars	14.31	.....	.....	6.55	.....
Ration cost, dollars	.....	46.76	.....	44.53	56.36
Total cost, dollars	.....	.....	61.07	51.08	56.36
Gain in carcass, pounds‡	54	329	383	322	322
Cost per pound carcass gain, cents	27.5	14.2	15.9	15.8	17.5
Cost per pound of live weight gain, cents	10.9	16.9	15.0	18.5	20.4

* 3.5 steers per acre stocking rate.
† 7.0 steers per acre stocking rate.
‡ Carcass weight corrected to 20 per cent fat and 17.3 per cent protein (Meyer *et al.*, 1960).

feeedlot. A successful attempt was made to finish all steers to equivalent fat content and carcass grade. All animals which were fattened in the feedlot or on pasture had equivalent fat content, grade, and marbling even though the animals fed in the feedlot following pasturing attained a much larger live weight to fiinish at approximately the same fat content.

A cost study on the various methods used in fattening steers was primarily compared on feed costs per carcass gain whereby initial carcass weights (representative steers slaughtered initially) are subtracted from final carcass weights (table 34). The carcass weight of the animals prior to the beginning of the trial and at the end of each phase was corrected to one equivalent containing 20 per cent fat and 17 per cent protein (Meyer *et al.,* 1960). This allowed correction for differences in fill and proportion of fat in the gain. It also corrects for differences in final values since it is assumed that all carcasses containing 20 per cent fat, which is midway between good and choice under the present grading system, would be of equivalent value. In this case, the most expensive carcass gains were those produced on pasture, primarily because of the greater fill (lower dressing percentage) in the steers and the lower fat content in the weight gain.

The feed cost of the carcass gain in the feedlot for the 88 days following the pasture period was low (14.2 cents) because the animals made a larger daily weight and energy gain. This can be considered an effect of compensatory growth since the daily gain was 3.19 pounds (table 33) while those fattened on pasture or in the feedlot gained 2.38 and 2.88 pounds, respectively, during the comparable 88-day period. It appears, therefore, that pasture which may produce a low rate and expensive gain as a sole energy source has an additional advantage which should be considered—its influence on compensatory growth in the feedlot following pasturing.

The total feed cost of the carcass gain for steers pastured for 122 days followed by a feedlot fattening of 88 days was 15.9 cents, approximately equal to that from those fattened on pasture. This indicates that the producer can use either system to advantage. Irrigated pasture, therefore, has a further role to economically feed and hold animals as a leveling method to even the supply of feeders to the feedlots. In addition, a larger live weight was produced when steers were pastured and then feedlot fattened to produce the same degree of fatness. This may have advantages under certain market conditions.

Cost figures calculated per pound of live weight gain (table 34) showed that pasture gains on a live weight basis were by far the least expensive when pasture was the only source of feed. This was not apparent when considering carcass gain corrected to equal fat and protein content. When calculations were made on live weight gain only, undue credit was given to animals having a larger fill in the gastrointestinal tract and less fat in the weight gain. This was apparent also when cost per pound of live weight gain in the feedlot following

pasture was compared to those fattened on pasture or in the feedlot. Economic considerations based on live weight gain, therefore, can produce erroneous results and it is suggested that economic studies made on growing and fattening animals consider using some equivalent measure such as fat corrected carcass.

Table 32 indicates that the net energy cost in California during the last 10 years was much cheaper from irrigated pasture than from the harvested feeds. Yet, data from table 34 indicates that pasture was the most expensive source for carcass (energy) gain. A study of the net energy requirements for maintenance and gain (table 35) indicates that 87 per cent of the net energy requirements for cattle fed on pasture only was for maintenance, while only 45–52 per cent of the energy requirement was for maintenance in the feedlot. The total cost per unit of net energy for both maintenance and gain, was less expensive from pasture than from the harvested feeds, but if the cost per unit of net energy required for gain was used as a base, pasture was the most expensive energy source.

Irrigated pasture can be economically used as an energy source of feed when compensatory growth which subsequently occurs in the feedlot is considered. In this case, the cost per unit of carcass gain was equivalent to those fattened immediately on pasture. A rancher, therefore, has a choice between these two systems in utilizing irrigated pasture. One system allows him to carry animals without purchasing harvested feeds. but if he is to get the most from his pasture he should retain ownership and fatten the steers for the compensatory growth which occurs in the feedlot following pasturing. In this case when animals were pastured, followed by feedlot fattening, the pasture charge could increase $7.87 per animal, $27.54 per acre, or $45.90 per season, to make the cost per unit of carcass gain equivalent to that obtained when steers were fattened immediately in the feedlot. This would allow a 60 per cent increase in pasture charges.

IRRIGATED PASTURE AS A PROTEIN SOURCE

The feed cost per pound of carcass gain was 17.5 cents for those fattened immediately in the feedlot, while those fattened immediately on pasture produced a gain which cost 15.8 cents. In the latter case, the pasture replaced primarily the supplemental feeds, cottonseed meal, molasses, alfalfa hay and oat hay, which were sources of protein, minerals, vitamins and fiber. When pasture was the only source of energy, the carcass gains cost 27 cents. From this it might be tentatively concluded that pasture fills its best role as a supplemental feed source rather than as an energy source because steers full-fed an energy source (barley) on pasture produced more inexpensive carcass gains compared to those fattened in the feedlot (table 35). The pas-

Table 35
ENERGY UTILIZATION AND COST FOR STEERS

	Pasture followed by feedlot			Pasture fattening	Feedlot
	Pasture	Feedlot	Total		
Net energy*					
for maintenance, megcals	558	590	1,048	564	617
for gain, megcals	85	601	686	580	572
Total, megcals	643	1,091	1,734	1,144	1,189
Maintenance requirement, per cent	87	45	60	49	52
Cost per megcal. net energy:					
Total, cents†	2.22	4.28	3.52	4.46	4.74
Gain, cents‡	16.83	7.78	8.90	8.80	9.85

* Based on requirements given by Garrett *et al.* (1959).
† Cost for net energy used for both maintenance and gain.
‡ Cost for net energy used for gain only.

ture charge would have to increase by $5.28 per animal or $36.96 per acre to make pasture fattening as expensive as fattening directly in the feedlot. This would be an increased charge of 81 per cent or $61.60 per season for pasture.

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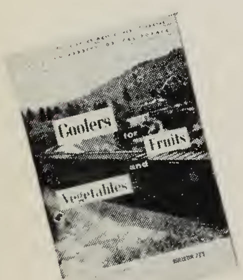

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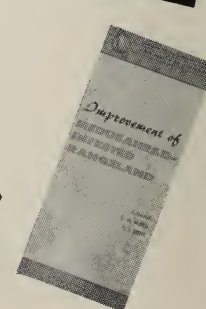

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